International Journal of Advanced Technology and Engineering Exploration, Vol 11(119)
ISSN (Print): 2394-5443 ISSN (Online): 2394-7454
http://dx.doi.org/10.19101/IJATEE.2024.111100648

Review Article

Revealing trends: a 25-year bibliometric analysis of MANETs in disaster research publications using the Scopus database

Fatin Fazain Mohd Affandi[1], Nor Aida Mahiddin[1, 2*], Zarina Mohamad[1] and Nurul I. Sarkar[3]
Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin (UniSZA), Terengganu, Malaysia[1]
East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin (UniSZA), Terengganu, Malaysia[2]
Auckland University of Technology, Computer Science and Software Engineering, Auckland, New Zealand[3]

Received: 27-April-2024; Revised: 19-October-2024; Accepted: 22-October-2024

Abstract
Mobile ad hoc networks (MANETs) are crucial for disaster management, enabling communication and coordination when traditional infrastructures are unavailable or compromised. This study provides a bibliometric analysis of global research on MANETs in disaster scenarios, covering publications from 1997 to 2022 sourced from Scopus. From an initial pool of 1,794 articles, 1,745 articles were selected for detailed review and analysis. The analysis examines trends in publication volumes, patterns of co-authorship among countries and institutions, and the co-occurrence of author keywords. The findings reveal a significant increase in MANET disaster-related publications since 2005, with India, the United States, and China leading in contributions and international collaboration. This study highlights the evolving research landscape and identifies critical areas for future investigation. It indicates the need for continued exploration into MANETs' role in disaster scenarios to enhance their practical application and effectiveness.

Keywords
Mobile ad hoc network, Disaster management, Bibliometric analysis, Scopus database, Trend.

1.Introduction
Wireless communication systems are integral to various applications, including mobile telephony, radio and television (TV) broadcasting, satellite communication, wireless local area networks (LANs), and military operations [1]. Mobile ad hoc networks (MANETs) represent a dynamic and rapidly evolving research area among these systems. MANETs are self-configuring, decentralised networks composed of mobile nodes collaborating to establish communication without relying on fixed infrastructure [2–4]. They are particularly valuable when traditional communication networks are unavailable or compromised, such as in military operations or disaster response. MANETs face significant challenges despite their advantages, often categorised as "MANET disasters."

These disasters include a range of disruptions, such as node failures, network partitions, communication delays, security breaches, and resource exhaustion. The inherent mobility of nodes, dynamic changes in network topology, and limited power resources exacerbate these challenges. As a result, MANETs are susceptible to communication breakdowns, data loss, security vulnerabilities, and decreased reliability. Addressing these issues requires advancements in network protocols, routing algorithms, resource management, and security mechanisms to enhance network robustness and ensure reliable communication [5].

The primary objective of this study is to conduct a comprehensive bibliometric analysis of research on MANETs in disaster scenarios, covering the period from 1997 to 2022. The study aims to identify and analyse global research trends, the contributions of leading academic institutions, and the roles of prominent countries and influential authors in this field. Additionally, the study seeks to propose potential collaborative opportunities and future research directions based on current patterns, specifically focusing on enhancing the practical

*Author for correspondence

application and effectiveness of MANETs in disaster management.

Recent research has increasingly focused on understanding and mitigating MANET disasters, providing valuable insights into this complex field. However, there is a need for a systematic analysis of global research trends and patterns in MANET disaster scenarios. Current studies have highlighted the importance of frameworks for disaster resilience and optimal decision-making [6], but a comprehensive examination of worldwide research patterns remains lacking.

This study aims to fill this gap by conducting a detailed bibliometric analysis of MANET disaster research over the past twenty-five years using Scopus databases. It explores the contributions of leading academic institutions, prominent nations, and influential authors. Furthermore, it identifies key terminologies and thematic areas and proposes potential collaborative opportunities and research directions based on current trends. Understanding these research trends is crucial for researchers, policymakers, and practitioners to address existing shortcomings and tackle the pressing challenges in MANET disaster communication [7–9].

In subsequent sections, this study addresses specific research questions related to the evolution of MANET disaster research, the effectiveness of current approaches, and the potential for future advancements in the field. The paper structure is organised into sections. Section 2 presents the bibliometric analysis methodology, which involves several key steps such as search strategy, selection criteria, data cleaning, data analysis, determining key questions, and intended outcomes. Section 3 offers a detailed literature review highlighting key points of related works and current challenges in MANET. Section 4 provides a comprehensive analysis of the bibliometric data and findings along with the study limitations. The paper concludes with section 5, summarising the key findings and suggesting future research directions.

2.Bibliometric analysis methodology

This study employs a detailed bibliometric analysis methodology to explore research trends in MANET disaster scenarios from 1997 to 2022. Unlike traditional review articles, which often summarise current advancements, innovations, and potential paths within a specific study field, the bibliometric analysis offers a different perspective on the relevance of research trends. This bibliometric analysis methodology involves several key steps:

(i)Data Sources: The data for this study were extracted from Scopus database, a comprehensive and reliable academic database known for its wide coverage of peer-reviewed literature. No additional databases (e.g., Google Scholar or Web of Science (WoS)) were included to maintain consistency.
(ii)Search Strategy: Articles were extracted from the Scopus database using a carefully constructed search strategy, focusing on keywords like 'disaster,' 'emergency,' 'MANET,' and 'ad hoc network.' Exclusion criteria included non-research articles such as reviews and book chapters.
(iii)Inclusion and Exclusion Criteria: The inclusion and exclusion criteria are detailed in *Table 1*. These criteria were designed to focus the review on research articles that meet the relevancy and quality standards required for bibliometric analysis. For example, articles from 1997 to 2022 were included, while those from 2023 were excluded at this stage. The analysis was also restricted to publications in English.
(iv)Data Cleaning: The search results from the Scopus were refined again by excluding duplicates and irrelevant entries, resulting in 1,745 relevant publications. The extracted dataset also underwent filtration using a thesaurus to eliminate redundancy and irrelevant entries or keywords before they were analyzed using the chosen software tool.
(v)Analysis Using Visualization of Similarities (VOSviewer): Bibliometric maps (were generated using VOSviewer software), which visualise relationships between authors, institutions, and keywords. The software's functionalities were utilised to evaluate the strength of connections, identify influential research clusters, and map the evolution of research themes over time.
(vi)Research Questions: Three key questions have been highlighted and explained in subsection 2.5. These questions focus on identifying the main research trends, determining which countries and institutions are leading in this field, and analyzing the most frequently researched keywords and themes. These questions shape the analysis and help identify gaps and future directions.
(vii)Intended Outcomes: The outcomes include identifying leading contributors, emerging trends, and potential gaps in the current research presented in section 4 result and discussion. These insights aim to inform future research directions and collaborative efforts.

2.1Data source and search strategy

Scopus database is chosen as the primary source of bibliographic data due to its sophisticated search capabilities, inclusion of indexed publishers, and prominence as a leading repository of scholarly works in scientific disciplines [10]. The database's predominance of English-language publications also supports its selection of alternative sources [11]. Furthermore, Scopus is renowned for its reliable indexing of high-quality academic literature.

The search strategy was crafted to include all relevant publications in the MANET and disaster communication domains. The keywords were carefully selected to ensure a focus on disaster scenarios and ad hoc network systems, and articles were filtered to ensure they related directly to MANETs and emergencies. The search strategy specifically excluded review papers to focus on empirical research contributions in MANET disaster studies. Articles that did not match these criteria were excluded from the final dataset.

2.2Inclusion and exclusion criteria

The inclusion and exclusion criteria are detailed in *Table 1* to provide researchers with a clear understanding of what to include and exclude when entering the advanced search string on the Scopus website. The table focuses on publications from 1997 to 2022, excluding the year 2023.

Table 1 Inclusion and exclusion criteria for MANET disaster research articles (1997-2022)

Criteria	Inclusion	Exclusion
Time frame	Articles and conference proceedings published from beginning (1997) to 2022	Articles and conference proceedings published after 2022
Document type	Articles and conference proceeding	Review articles, book chapters, editorials
Language	English	Non-English articles
Database	Scopus	Articles not indexed in Scopus
Keywords	Articles and conference proceedings containing (“disaster” or “emergency”) and (“MANET” or “ad hoc network”) in title or abstract	Articles and conference proceedings not related to “disaster”, “emergency”, “MANET”, and “ad hoc network”.
Publication stage	Final publication stage	Early access or preprints
Subject Area	Computer Science	Irrelevant subject areas (e.g., humanities, arts, etc.)

Figure 1 shows a schematic illustration of the data extraction and study exclusion procedure. The data collection took place from February 10 to February 16, 2023, employing the Scopus database. The primary thematic focus guiding article selection was refined through the incorporation of terms such as "disaster," "emergency," "MANET," and "ad hoc network" present in both title and abstract fields, with the exclusion criterion applied to articles published in the ongoing year, 2023. The keyed search string was: TITLE-
ABS (("disaster" OR "emergency") AND ("MA
NET" OR "AD HOC
NETWORK")) AND (LIMIT-
TO (SRCTYPE , "p") OR LIMIT-
TO (SRCTYPE , "j")) AND (LIMIT-
TO (PUBSTAGE , "final")) AND (LIMIT-
TO (DOCTYPE , "cp") OR LIMIT-
TO (DOCTYPE , "ar")) AND (LIMIT-
TO (SUBJAREA , "COMP")) AND (EXCLUDE
(PUBYEAR , 2023)). The search string initially generated a total of 1794 articles.

2.3Data cleaning

A term was added to the search string to exclude review papers from our analysis, which turned up 49 works that might not be linked to our investigation. The title and abstract of this search query contained terms like review, recent, progression, crucial, overview, bibliometric, and potentiometric. The retrieved review article's electronic identifier (EID) functioned as a unique identifier in the Scopus database and was utilised to create further search keywords that would only yield research articles. Only research-focused publications remained after the final search query further filtered out traditional review articles, book chapters, and other possibly irrelevant studies. This process improvement resulted in a decrease in the total number of publications to 1745 articles.

Data on the most active journals were compiled by classifying them according to the total number of articles produced over the specified period. Additionally, to incorporate single-country publication (SCP) data into evaluating the most

prolific countries and organisations, the search results were limited to each country using the term AFFILCOUNTRY. After the data were systematically combined and categorised based on several parameters, including significant topics, release years, sources, authors, affiliations, nations, fields of focus, and document formats, the number of residual publications came to 1745. Bibliometric information from the Scopus website was utilised to enhance the ranking. This included total articles and citations, CiteScore, and h-index. Furthermore, to gain comprehensive insights into the utilisation patterns of materials, a sub-theme was delineated focusing on MANET and its application in contexts of natural disasters.

Before the bibliometric maps were generated by the VOSviewer software, the extracted Scopus dataset consisted of the information from the finalized 1,745 articles undergoing filtration using a thesaurus to eliminate redundancy and irrelevant entries or keywords. This information was utilised to generate two distinct bibliometric maps that specifically examine co-authorship and co-occurrence.

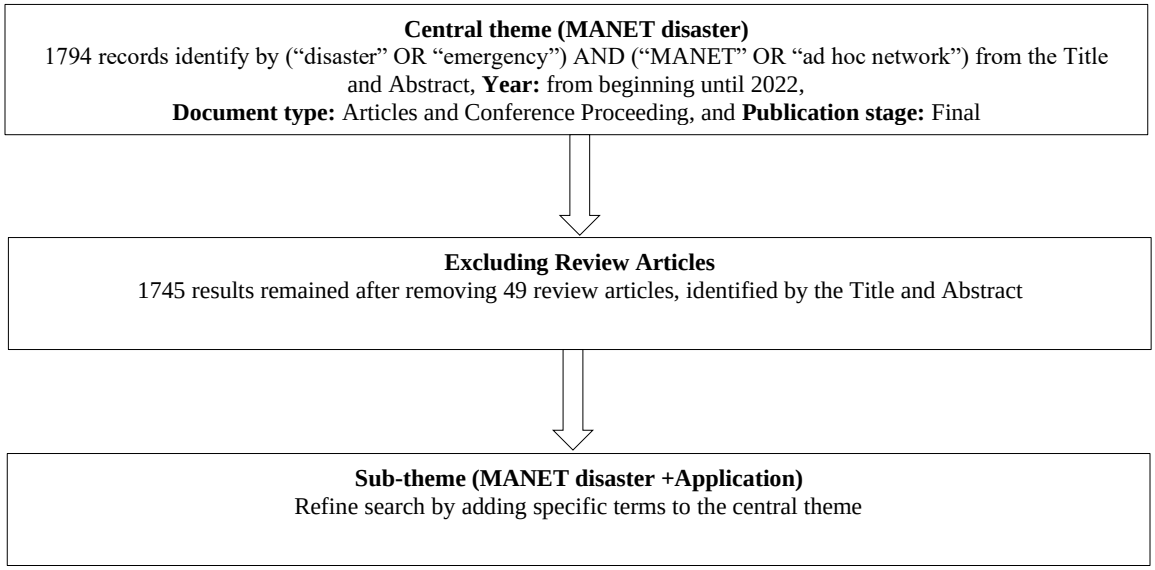

Figure 1 Research strategy on the data gathering procedure for main and sub-themes

2.4Analysis using VOSviewer software

In conducting bibliometric mapping for network analysis, commonly utilised software packages include VOSviewer, Pajek, Histiograph Cite (HistCite) Graph Maker, and Gephi [12]. In this study, we opted to utilise the VOSviewer software [13]. To generate bibliometric maps based on 1745 publications sourced from the Scopus database. The selection of VOSviewer was motivated by its extensive compatibility with various databases, including Scopus, WoS, Dimensions, Microsoft Academic, Lens, and Player Unknown Battle Mantra Ending in Domination (PubMed), rendering it an optimal tool for conducting such analyses [8]. VOSviewer facilitated the visualisation of pertinent entities, such as countries or author keywords, which were pivotal in creating bibliometric maps. Additionally, the software's functionality allowed for evaluating the strength of relationships between different entities quantified as numerical values for straightforward interpretation, with higher numerical values denoting stronger connections between items. Despite its limited resource requirements, it is underscored that VOSviewer stands out as one of the premier choices for conducting science mapping analyses, offering free accessibility without necessitating a subscription [8, 14].

The information from the 1745 articles was utilised to generate two distinct bibliometric maps that specifically examine co-authorship and co-occurrence. According to [15], the assessment of the connection intensity between two nations in co-authorship maps was based on the quantification of published publications featuring authors linked with both countries. The comprehensive magnitude of a specific nation's interconnections with other nations was denoted as the aggregate link strength. It is important to acknowledge that VOSviewer has a constraint in which an in-depth examination of links between nations can only be conducted for pairs of countries or the entire set of countries.

The connection strength in the co-occurrence maps represents the total frequency of articles containing the supplied search phrases [16]. For a thorough grasp of VOSviewer's capabilities and optimal utilisation, users can consult the software's official user guide, which is accessible on its website. This guide furnishes detailed, step-by-step instructions for navigating VOSviewer's functionalities. To be more precise, collaborative works are found using publication affiliations in the co-authorship map, while shared keywords are used in the co-occurrence map to identify collaborative works.

2.4.1Analysis of co-authorship

The co-authorship analysis is directed towards elucidating collaboration patterns among authors, aiding in the identification of prolific authors, the robustness of their collaborations, and the overall structure of the collaborative network embedded within the dataset [17]. In this study's co-authorship analysis, the countries affiliated with authors, extracted from 1745 research articles, were quantified and visualised. Initially, the VOSviewer software mapped 95 countries, encompassing 4255 authors. Subsequently, the dataset underwent filtration using a thesaurus to eliminate redundancy and irrelevant entries, resulting in a final tally of 76 countries. Following this refinement, countries were clustered based on geographical proximity, assigning them to continental clusters. Cluster 1 corresponds to Europe, cluster 2 to Asia, cluster 3 to South America, cluster 4 to North America, cluster 5 to Africa, cluster 6 to Oceania, and cluster 7 to Antarctica. This systematic categorisation facilitates the facile identification of countries affiliated with specific continents. The resultant map was created by the VOSviewer tool using a full counting approach in network visualisation mode. The map is presented in *Figure 4* in section 4.

2.4.2Analysis of co-occurrence

In this study, the co-occurrence analysis exclusively relied on author keywords extracted from articles, omitting the indexed keywords provided by the Scopus database. A total of 3520 author keywords were derived from 1745 articles. The process of constructing co-occurrence maps commenced with the input of author keywords into the VOSviewer software, following a meticulous filtering regimen to eliminate any instances of duplication. Keywords such as "manet," "manets," " MANET," " MANET," and " MANETs" were recategorized as " MANETs." Subsequently, 3459 keywords from this refinement process were employed in map generation. Given the substantial number of keywords, the minimum co-occurrence threshold was set at 5, extracting 135 keywords for map creation. These maps are presented in overlay visualisation mode (created by the VOSviewer tool), where the year and the average number of associated articles are denoted by the colour and intensity of the connections between phrases, respectively. The map is presented in *Figure 5* in Section 4.

2.5Research questions

The bibliometric analysis in this study is structured around several key research questions, designed to provide a comprehensive overview of trends in MANET disaster research from 1997 to 2022. This study is guided by the following key questions:

(i) What are the main trends in MANET disaster research between 1997 and 2022?
(ii) Which countries and institutions lead in this field?
(iii) What are the most frequently researched keywords and themes?

By addressing these questions, the study seeks to uncover not only the evolution of MANET disaster research but also the thematic areas that have received the most attention over time. The analysis provides insights into the relationships between various contributors and the impact of their work, helping to map out areas of strength and gaps in the existing body of knowledge.

2.6Intended outcomes

The intended outcomes of this analysis are to highlight the leading contributors, emerging trends, and potential gaps in current research. These findings, presented in section 4, offer a roadmap for future research directions, pointing to areas where further investigation is necessary. By identifying collaboration opportunities and the progression of research themes, this study aims to inform both current and future scholars about the landscape of MANET disaster research and foster collaborative efforts that address the challenges and opportunities in this evolving field.

3.Literature review

Various methodologies have been employed to study academic literature, spanning qualitative and quantitative approaches. Traditional literature reviews, characterised by a subjective synthesis of prior works, have been increasingly supplemented by more objective and quantitative methods. Recent advancements have seen the rise of bibliometric and social network analysis techniques, which leverage

citation and co-citation data to map the intellectual structure of research fields [18, 19]. These methods offer an objective lens to view the evolution and interconnections within a body of knowledge, making them particularly appealing for their impartiality and thoroughness [20].

This study identifies several key topics within the domain of MANETs that are critical to advancing their application in disaster scenarios. These topics include:

(i) Network Protocols: Development of robust protocols tailored to dynamic and unreliable conditions typical of disaster environments.
(ii) Routing Algorithms: Innovations in routing algorithms that address challenges such as node mobility, network partitioning, and limited power resources.
(iii) Resource Management: To maintain network performance and reliability, strategies for optimising limited resources, including bandwidth and energy.
(iv) Security Mechanisms: Enhanced security protocols to mitigate risks such as data breaches, malicious attacks, and unauthorised access.

Discussing these topics in greater detail highlights their relevance to disaster management and indicates the need for continued exploration to improve MANETs' resilience and efficacy in such scenarios. Several seminal works have utilised bibliometric techniques to explore into specific areas of network research. For instance, a study on MANETs employed bibliometric and social network analysis to chart the development of the field from 2001 to 2010, providing insights into the growth and intellectual structure of MANET research [18]. Complementing this, research on vehicular ad hoc networks (VANETs) has been comprehensive, with significant contributions highlighting the architecture, challenges, and trends within the field [19–22]. This research serves as a foundational reference for understanding the complexities and evolving landscape of VANETs.

In addition to foundational studies, targeted explorations have been conducted into specific aspects of network research. A survey focusing on the security challenges across MANETs, VANETs, and flying ad hoc networks (FANETs) underscores the vulnerabilities these networks face and outlines critical areas for security improvement [20, 23]. Furthermore, exploring MANET interoperability has examined various proposals and techniques to enhance communication across different MANET systems, identifying advancements and ongoing limitations [24].

Recent works have also provided valuable insights into emerging trends and challenges in the field. For example, a comprehensive review of ad hoc networks discusses the evolution of these networks and emphasises challenges such as scalability and energy efficiency [25]. Similarly, research examining VANETs over the past decade has highlighted key trends, including an increased focus on simulation for protocol evaluation, while also noting issues related to the credibility of simulation results [26].

The latest contributions to the field continue to expand our understanding of VANETs and MANETs. A recent review discusses integrating emerging technologies like software-defined network (SDN) and the internet of vehicles (IoV) within VANETs, identifying crucial areas for future research [27]. Another study highlights the application of artificial intelligence (AI) and SDNs in VANETs, addressing significant technical challenges and exploring potential advancements [28]. A recent bibliometric analysis has provided a broad overview of wireless networks, including MANETs and opportunistic networks (OppNets), and outlined various routing protocols used in these networks [29]. *Table 2* summarises each related work by highlighting their methodology, findings, limitations, and future works suggested by the authors. Together, these studies illustrate network research's dynamic and evolving nature, showcasing the breadth of approaches and insights that have emerged in recent years.

Table 2 The related work that explores the research trends of the ad hoc networks for the past years

Work	Methodology	Findings	Limitations	Suggested future research
[18]	Bibliometric and co-citation analysis of MANET research from 2000-2010.	MANET research is primarily published in generalist journals; the field lacks a distinct identity.	Citation bias and data source limitations; lack of formal models.	Improve citation metrics and expand data sources; explore formal models for validation.
[19]	Comprehensive review of VANET literature,	Identified trends in routing, security, and	Lack of standard protocols and security measures for	Develop more secure, scalable protocols for

Work	Methodology	Findings	Limitations	Suggested future research
	focusing on routing and security.	layered network architecture for VANETs.	real-world deployment.	VANETs; enhance real-world testing.
[20]	Survey of security challenges across MANETs, VANETs, and FANETs.	Highlighted the vulnerabilities in these networks and the need for tailored security solutions.	Lack of empirical data and standardization in security measures.	Conduct empirical studies; develop regulatory frameworks for unmanned aerial vehicle (UAV) operations in FANETs.
[21]	Evaluation of VANET routing protocols.	Identified challenges in routing and traffic management in VANETs.	Issues with implementation and scalability in real-world environments.	Develop solutions for traffic management and routing scalability in urban settings.
[22]	Longitudinal analysis of VANET applications, reviewing historical trends and future directions.	Highlights challenges in VANETs and emphasizes distinct services, but lacks empirical data and solutions for scalability.	Theoretical focus, lacks real-world case studies and scalability solutions.	Explore real-world VANET deployment, focus on scalability and unique VANET characteristics.
[23]	Bibliometric analysis using WoS database and systematic literature review (SLR) based on Kitchenham's methodology.	Shows ongoing interest in ad hoc network security, with key focus areas identified.	Lack of clear classification, misclassification of solutions, and outdated frameworks.	Develop new taxonomies and frameworks for security threats; explore underdeveloped topics identified in the analysis.
[24]	Review of formalization techniques and simulation tools in MANETs.	Identified common simulation tools and the lack of formal models in the majority of studies.	Heavy reliance on simulations without real-world testing; lack of standardization.	Standardize simulation environments; improve formal models and conduct real-world validations.
[25]	Literature review on advancements in ad hoc networks.	Found that machine learning is becoming increasingly important for optimizing network protocols.	Insufficient empirical research and real-world application of theoretical insights.	Focus on machine learning techniques to optimize protocols; conduct more real-world studies.
[26]	Analysis of 283 VANET studies from 2007-2017, reviewing major conferences and journals.	Steady interest in VANET research but transparency issues in simulation methods; limited studies on safety and efficiency.	Lack of detailed simulation transparency and insufficient research on protocol performance.	Focus on advanced topics like geo-social mobility modeling and integrating new tools for vehicular communication.
[27]	Comprehensive review of VANET advancements, with a focus on future challenges.	Key challenges identified include dynamic vehicle mobility, resource constraints, and testing protocol limits.	Limited by dynamic vehicle mobility, resource constraints, and persistent routing issues.	Prioritize low-latency, high-bandwidth applications; focus on effective deployment strategies.
[28]	Literature review from various databases focusing on challenges and solutions in VANET routing.	Stresses the importance of leveraging emerging technologies for routing and congestion control.	Narrow focus on AI methods and insufficient real-world testing.	Prioritize real-world validations; explore AI and SDN for improved security and routing.
[29]	Bibliometric analysis of wireless networks from 1996 to 2022, focusing on Wireless Sensor Networks (WSNs) and routing.	Identified major contributors (USA, China, India) and research areas like WSNs.	Exclusion of certain protocols and lack of simulation environment for testing.	Address gaps through systematic reviews and develop new protocols for wireless network research.

3.1Current challenges in MANETs

Despite the potential benefits of MANETs in disaster management, several major challenges hinder their optimal deployment and performance. Below is the summarisation of the key challenges, which include:

(i) Scalability: MANETs are inherently limited by their scalability due to the dynamic nature of their topology and the mobility of nodes. As the number of nodes increases, efficient communication becomes difficult, leading to higher latency and potential communication failures [25].

(ii) Energy efficiency: Nodes in MANETs are typically battery-powered, making energy conservation a critical concern. The constant movement and reconfiguration of nodes drain battery life rapidly, necessitating the development of energy-efficient protocols and algorithms to ensure network sustainability during extended operations [24].

(iii) Security: Security remains a paramount challenge for MANETs, particularly in disaster scenarios where network infrastructure is compromised or non-existent. The absence of centralised control makes MANETs vulnerable to attacks, including eavesdropping, spoofing, denial of service (DoS), and data tampering [20, 23].

(iv) Network reliability: Ensuring reliable communication in MANETs is challenging due to frequent changes in network topology, link failures, and variable quality of service (QoS). These issues are exacerbated in disaster scenarios, where environmental conditions can cause further disruptions.

(v) Interoperability: MANETs often must operate alongside other communication networks and technologies, such as satellite and cellular networks. Achieving seamless interoperability between different network types and standards is a significant challenge that requires novel integration techniques and standardisation efforts [24, 26, 28].

(vi) Limited bandwidth: Bandwidth constraints are critical for MANETs, especially in dense environments where multiple nodes compete for the same communication channels. This limitation can lead to congestion, packet loss, and reduced overall network performance [7–9].

(vii) Context-specific challenges: In disaster scenarios, MANETs face additional context-specific challenges, such as environmental interference, node mobility due to human or vehicle movement, and unpredictable obstacles. Developing robust protocols adapting to these unique conditions is an ongoing challenge [29].

Addressing these challenges is crucial for enhancing the effectiveness of MANETs in disaster management. Innovative solutions and advancements in protocols are needed to improve scalability, energy efficiency, security, and network reliability. Moreover, developing strategies to overcome interoperability and bandwidth constraints and adapting to context-specific challenges will contribute to more robust and reliable MANET implementations. By tackling these issues, researchers and practitioners can better harness the potential of MANETs to provide critical communication support in disaster situations, ultimately improving response efforts and outcomes.

4.Result and discussion

This section provides an overview of research trends from inception until 2022. Additionally, it explores the preferred conference proceedings and journals in the domain. Analysing co-authorship and co-occurrence networks enables a comprehensive description of the leading countries, institutions, and authors. The study also presents commonly used keywords by researchers, accompanied by explanations of terminology and concepts. Finally, the limitations of this study are discussed.

4.1Production of the research article and research interest

Over 25 years, 1745 research articles addressing the MANET disaster have been published. As depicted in *Figure 2*, examining the publication trend concerning the MANET disaster and its implications unveils intriguing patterns across the years. Singular publications were recorded in 1997 and 1999, respectively. Subsequently, in 2000, the number of publications escalated to four, signifying an initial surge in research interest. However, in 2001, the count dwindled to a solitary publication.

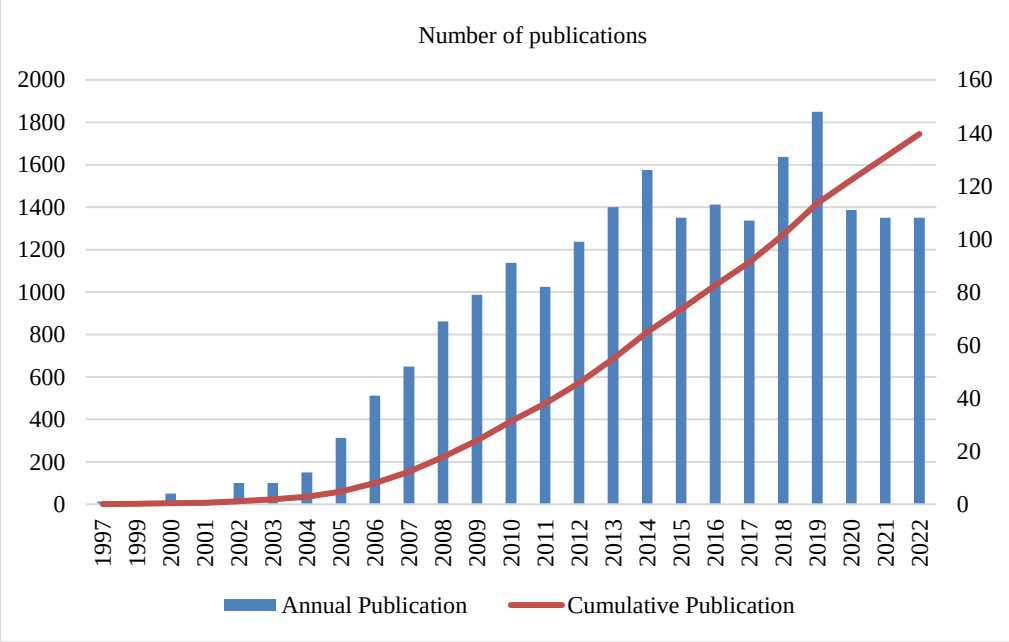

Figure 2 Annual and cumulative number of MANET disaster research articles indexed in Scopus (1997-2022)

From 2002 onwards, steady growth in publications can be observed. 2004 marks a significant increase, with 12 publications, followed by a substantial rise in 2005, reaching 25. This growth trend continued until 2008, when the number of publications reached 69—the subsequent years witnessed a consistent increase, with the highest number of publications recorded in 2019, with 148 publications.

From 2020 onwards, a slight decline in the publication count is observed, with 111 publications in 2020, followed by 108 publications in 2021 and 2022. Although this decline may indicate a temporary fluctuation, further investigation is necessary to determine if this trend will persist or rebound.

The analysis extends beyond the MANET domain by comprehensively evaluating various methodologies in recent studies. These methodologies include bibliometric mapping, social network analysis, and trend analysis, which provide a multi-faceted perspective on the evolution of research in MANETs. For instance, bibliometric mapping helps visualise collaboration patterns among authors and institutions, while social network analysis reveals key clusters and influential actors within the research network. By evaluating these methodologies, the study highlights innovative approaches that have contributed to a deeper understanding of MANETs' application in disaster scenarios and identifies gaps where further research is needed.

4.2Preferred publication

4.2.1Preferred conference proceeding

Table 3 describes the top 10 most productive conference proceedings on MANET disaster research. *Table 3* include their total productivity (TP) percentage, CiteScore, the most cited article, the number of times it has been cited, field-weighted citation impact (FWCI), and the publisher.

Table 3 demonstrates that the IEEE Vehicular Technology Conference exhibits the highest TP. Notably, the most cited article within this conference proceedings centers on the performance study of live video streaming over highway VANETs. [30], garnering 59 citations, signifying its paramount importance in the field. Moreover, the article's relatively high FWCI of 2.48 substantiates its substantial impact. Claiming the second position in terms of TP, the IEEE International Conference on Communications features prominently. The most cited article within this conference discusses enhancing the security of VANETs through an AEMA scheme [31]. Similarly, this article has amassed 59 citations and boasts a high FWCI of 5.9, thus illustrating its influential and well-received status within the research community. As for the ACM International Conference Proceeding Series, it ranks third in TP. Investigating the role of the Internet infrastructure in vehicular grid communications [32], the most cited article within this series, while having obtained 22 citations,

presents a relatively low FWCI of 0.57, suggesting a comparatively limited impact on the top-ranked articles. Securing the fourth spot in TP, Procedia Computer Science showcases its most cited article, which delineates a VANET-based vehicle tracking module for a safe and efficient road transportation system [33]. Garnering 18 citations, this article has made a notable contribution to the field, as evidenced by its FWCI of 1.67 indicates a moderate impact.

The IEEE Region 10 Annual International Conference Proceedings TENCON is in the fifth position in TP. The most cited article of this conference revolves around an efficient, adaptive, and robust protocol (E-ARP) for effective data communication in VANETs [34]. However, with only 3 citations and an FWCI of 0.0, it becomes apparent that its impact has not been substantial. The ICCT Proceedings claims the sixth spot in TP. Its most cited article concentrates on a multi-hop broadcast scheme for propagating emergency messages in VANET [35]. In contrast, this article has accumulated 32 citations and a relatively high FWCI of 3.31, underscoring its significant impact on the field.

Ranking seventh in TP, the proceedings International Conference on Distributed Computing Systems showcase their most cited article, which explores into receiver consensus and on-time warning delivery for vehicular ad-hoc networks [36]. Boasting 14 citations and an FWCI of 2.19, this article has made a notable impact. The Proceedings of SPIE The International Society for Optical Engineering occupy the eighth position in TP. The most cited article within this conference proceedings highlights the creation of Wireless Fiber (Wi-Fi) Bluetooth mesh networks for crisis management applications [37]. However, as of now, this article has not received any citations, implying a limited impact in the field. Securing the ninth position in TP, the Proceedings IEEE Symposium on Computers and Communications present their most cited article, which deliberates on a model for designing scalable and efficient adaptive routing approaches in emergency ad hoc communications [38]. With 8 citations and an FWCI of 0.87, this article has made a modest impact. The Proceedings of the Annual International Conference on MOBICOM round up the top 10 list in TP. The most cited article within this conference examines research challenges in environmental observation and forecasting systems [39]. Notably, with an impressive 135 citations and a high FWCI of 3.94, this article has exerted significant influence in the field.

The analysis of the top 10 most productive conference proceedings on MANET disaster research reveals a hierarchy of TP, with the IEEE Vehicular Technology Conference and the IEEE International Conference on Communications claiming the top two positions. These conferences showcase articles with notable citation counts and high FWCI scores, indicating their substantial contributions and influence within the research community. However, it is important to note that the impact of articles varies across different conference proceedings, with some articles demonstrating limited influence despite their citation counts.

Table 3 Top 10 most productive conference proceedings on MANET disaster research (1997-2022) with most cited articles

Rank	Journal	TP (%)	CiteScore	The most cited article	Times cited	FWCI	Publisher
1.	Institute of Electrical and Electronics Engineers Inc. (IEEE) Vehicular Technology Conference	2.72% (29)	2.3	Performance study of live video streaming over highway VANETs	59	2.48	IEEE
2.	IEEE International Conference on Communications	2.06% (22)	3.9	Aggregated Emergency Message Authentication (AEMA) scheme for enhancing the security of VANETs	59	5.9	IEEE
3.	Association for computing machinery (ACM) International Conference Proceeding Series	1.97% (21)	1.0	Vehicular grid communications: The role of the Internet infrastructure	22	0.57	ACM Digital Library
4.	Procedia Computer Science	0.84% (9)	3.6	VANET based vehicle tracking module for safe	18	1.67	Elsevier B.V.

Rank	Journal	TP (%)	CiteScore	The most cited article	Times cited	FWCI	Publisher
				and efficient road transportation system			
5.	IEEE Region 10 Annual International Conference Proceedings Technical Conference (TENCON)	0.66% (7)	1.4	E-ARP: An efficient, adaptive and robust protocol for effective data communication in VANETs	3	0.0	IEEE
6.	International Conference on Communication Technology (ICCT) Proceedings	0.56% (6)	0.4	A Multi-Hop Broadcast scheme for propagation of emergency messages in VANET	32	3.31	IEEE
7.	Proceedings International Conference on Distributed Computing Systems	0.56% (6)	5.3	Receiver consensus: On-time warning delivery for VANETs	14	2.19	IEEE
8.	Proceedings of Society of Photo Instrumentation Engineers (SPIE) The International Society for Optical Engineering	0.47% (5)	0.9	Creating Wi-Fi bluetooth mesh network for crisis management applications	0	0	SPIE Digital Library
9.	Proceedings IEEE Symposium on Computers and Communications	0.38% (4)	2.1	A model for designing scalable and efficient adaptive routing approaches in emergency ad hoc communications	8	0.87	IEEE
10.	Proceedings of the Annual International Conference on Mobile Computing and Networking (MOBICOM)	0.38% (4)	8.2	Research challenges in environmental observation and forecasting systems	135	3.94	ACM Digital Library

4.2.2Preferred journal

Table 4 explains the top 10 most productive journals on MANET disaster research. The TP percentage, CiteScore, the most cited article, the number of times it has been cited, FWCI, and the publisher are shown in detail through the provided table below.

As indicated by *Table 4*, Wireless Personal Communications emerges as the top-ranked journal, boasting a TP percentage of 5.74% and a CiteScore of 3.5. Notably, the journal's most cited article, titled "A collision alleviation scheme for IEEE 802.11p VANETs,"[40] garners 33 citations. Moreover, this article attains an FWCI of 1.89, signifying a moderate impact. Published by Springer Link, Wireless Personal Communications exhibits a broad focus on wireless communication topics, encompassing VANETs. IEEE Access claims the second position as the most productive journal, with a TP percentage of 4.86% and a commendable CiteScore of 6.7. The article with the highest number of citations in this journal, titled "Trust aware secure energy-efficient hybrid protocol for MANET,"[41] receives 55 citations. Impressively, this article boasts an FWCI of 10.32, demonstrating a high impact. Published by the IEEE, IEEE Access covers a wide array of topics and has a substantial influence in the field of MANET disaster research.

Table 4 Top 10 most productive journals on MANET disaster research (1997-2022) with most cited articles

Rank	Journal	TP (%)	CiteScore	The most cited article	Times cited	FWCI	Publisher
1.	Wireless Personal Communications	5.74% (39)	3.5	A collision alleviation scheme for IEEE 802.11p VANETs	33	1.89	Springer Link
2.	IEEE Access	4.86% (33)	6.7	Trust aware secure energy efficient hybrid protocol for MANET	55	10.32	IEEE
3.	Ad Hoc Networks	3.24% (22)	9.5	Trust based routing mechanism for securing optimized link state routing (OLSR)-based MANET	93	5.04	Elsevier B.V.
4.	Institute of Electronics, Information and Communication Engineers (IEICE)	2.50% (17)	1.6	Information and communication technology and electric vehicles - Paving the way towards a smart community	18	1.54	IEICE
5.	International Journal of Communication Systems	2.50% (17)	3.7	Cluster-based emergency message dissemination strategy for VANET using V2V communication	35	2.8	John Wiley and Sons Ltd
6.	International Journal of Distributed Sensor Networks	2.36% (16)	4.2	A Novel Real Time Framework for Cluster-Based Multicast Communication in VANETs	21	1.27	Hindawi Limited
7.	Wireless Communications and Mobile Computing	2.21% (15)	3.5	A survey and comparative study of simulators for VANETs	199	8.63	John Wiley & Sons, Ltd.
8.	IEEE Transactions on Intelligent Transportation Systems	2.21% (15)	13.7	A multi-hop broadcast protocol for emergency message dissemination in urban VANETs	139	9.12	IEEE
9.	EURASIP Journal on Wireless Communications and Networking	1.77% (12)	5.6	Connectivity analysis of one-dimensional VANETs in fading channels	45	1.68	SpringerOpen
10.	Journal Of Theoretical and Applied Information Technology	1.62% (11)	1.3	Identity-based cryptography for MANETs	33	3.73	Asian Research Publishing Network

Moreover, Ad Hoc Networks secures the third position with a TP percentage of 3.24% and a remarkable CiteScore of 9.5. The journal's most cited article, titled "Trust based routing mechanism for securing OSLR-based MANET,"[42] receives 93 citations. Notably, this article achieves an FWCI of 5.04, indicating a substantial impact. Published by Elsevier B.V., Ad Hoc Networks specialises in ad hoc and sensor networks research, establishing itself as a prominent venue for research in this field. IEICE Transactions on Communications occupies the fourth rank, boasting a TP percentage of 2.50% and a CiteScore of 1.6. The most cited article within this journal focuses on the relationship between information and communication technology and electric vehicles [43], garnering 18 citations. Moreover, with an FWCI of 1.54, the article suggests a moderate impact. Published by the IEICE, this journal encompasses various aspects of communication technology, including MANETs. The International Journal of Communication Systems is the fifth-ranked journal, sharing the same TP percentage (2.50%) as IEICE Transactions on Communications. However, it surpasses with a higher CiteScore of 3.7. The most cited article in this journal, accumulating 35 citations, examines a cluster-based emergency message dissemination strategy for VANET utilising V2V communication

[44]. The FWCI of 2.8 suggests a moderate impact. This journal, published by John Wiley and Sons Ltd, focuses on various communication systems and technologies, including VANETs. The International Journal of Distributed Sensor Networks secures the sixth position with a TP percentage of 2.36% and a CiteScore of 4.2. The most cited article, encompassing 21 citations, introduces a novel real-time framework for cluster-based multicast communication in VANETs [45]. However, the article's FWCI is relatively low at 1.27, suggesting a lower impact. Published by Hindawi Limited, this journal covers distributed sensor networks and their applications, including research related to MANETs.

Moreover, Wireless Communications and Mobile Computing holds the seventh position, achieving a TP percentage of 2.21% and a CiteScore of 3.5. The journal's most cited article is a survey and comparative study of simulators for VANETs [46], amassing a significant number of citations (199). Remarkably, this article's FWCI is 8.63, indicating a substantial impact. This journal, published by John Wiley & Sons, Ltd., concentrates on wireless communication and mobile computing, including VANET research. Simultaneously, IEEE Transactions on Intelligent Transportation Systems shares the seventh position with a TP percentage of 2.21%, akin to Wireless Communications and Mobile Computing. Nonetheless, it boasts the highest CiteScore among the top 10 journals, standing at 13.7. The most cited article within this journal, with 139 citations, presents a multi-hop broadcast protocol for emergency message dissemination in urban VANETs [47]. Significantly, the article's FWCI of 9.12 suggests a notable impact. Published by the IEEE, IEEE Transactions on Intelligent Transportation Systems focuses on intelligent transportation systems, encompassing VANET research.

EURASIP Journal on Wireless Communications and Networking ranks ninth with a TP percentage of 1.77% and a CiteScore of 5.6. The most cited article in this journal, garnering 45 citations, investigates the connectivity analysis of one-dimensional VANETs in fading channels [48]. Furthermore, with an FWCI of 1.68, the article suggests a moderate impact. Published by SpringerOpen, this journal covers diverse topics in wireless communications and networking, including VANET research. The Journal of Theoretical and Applied Information Technology secures the tenth position with a TP percentage of 1.62% and a comparatively lower CiteScore of 1.3. The journal's most cited article, accumulating 33 citations, explores into identity-based cryptography for MANETs [49]. However, the article's high FWCI of 3.73 indicates a relatively higher impact. Published by the Asian Research Publishing Network, this journal encompasses theoretical and applied aspects of information technology, including MANET research.

The analysis of the top 10 most productive journals on MANET disaster research reveals that IEEE journals, including IEEE Access and IEEE Transactions on Intelligent Transportation Systems, have a significant presence in this field. Furthermore, reputable publishers such as Springer, Elsevier, John Wiley & Sons, and Hindawi contribute to disseminating research in this area. The analysis also demonstrates various research topics covered in these journals, including trust-based routing, energy efficiency, emergency message dissemination, and communication protocols in VANETs. Researchers and practitioners in the field of MANET disaster research can refer to these journals to explore the latest advancements, innovative solutions, and impactful articles in this domain.

4.3Leading countries and top institutions

Figure 3 displays the top 15 countries in a map view. Meanwhile, *Table 5* lists the top 15 countries and academic institutions contributing the most publications. It also includes additional information such as the total publications of a given country (TPc), the percentage of SCP (%), the most productive academic institution, and the total publications of a given educational institution (TPi) [50].

India occupies the first position with a significant number of 444 total publications, and an impressive 92.57% of these publications are from single-country contributions. Anna University is India's most productive academic institution, with 13 publications. This suggests a strong research presence in India and a focus on domestic collaborations. The United States follows India, with 216 total publications. Although the percentage of SCPs is lower than India at 66.20%, it is still a substantial contribution. The University of Illinois Urbana-Champaign and the University of California are tied as the most productive academic institutions in the United States, each with 9 publications. This indicates a diverse research landscape in the US with multiple leading institutions.

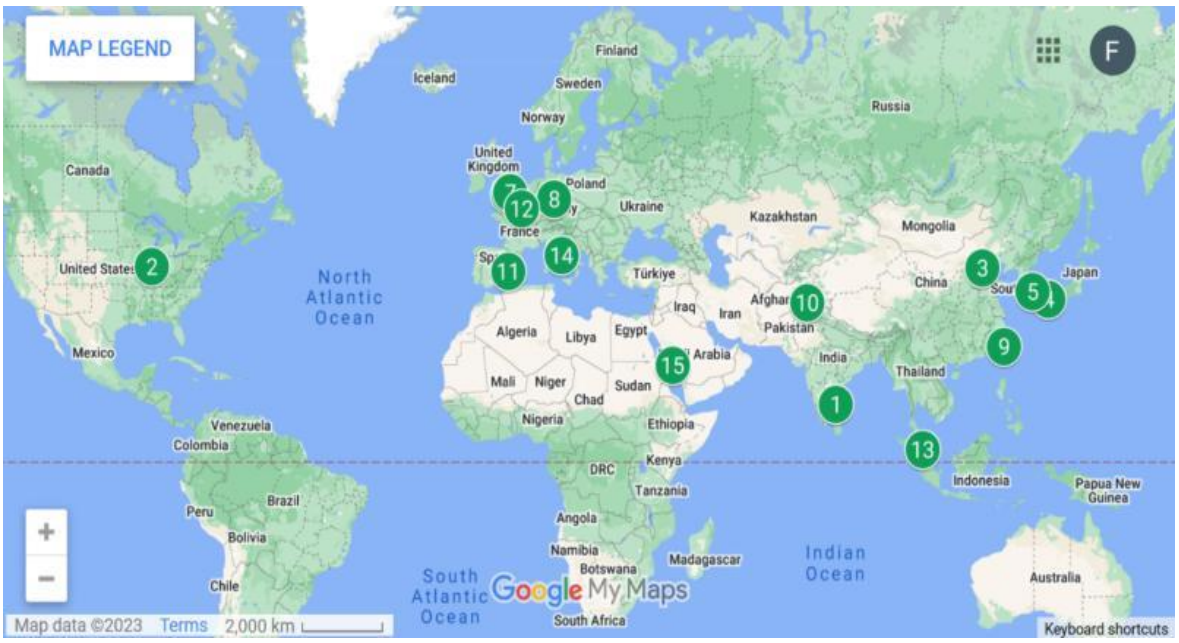

Figure 3 The top 15 countries and academic institutions that make the most publications

China takes the third position, with 209 total publications, and 68.90% of these publications are from single-country contributions. Beihang University emerges as the most productive academic institution in China, with 10 publications. The high percentage of SCPs strongly emphasises national research collaboration in China. Japan ranks fourth, with 175 publications, and 81.14% are from single-country contributions. Hiroshima City University is Japan's most productive academic institution with 18 publications. This suggests a strong focus on domestic research partnerships and a robust research output within the country.

The dominance of countries such as India, the United States, and China not only highlights their prolific contributions in terms of publication volume but also indicates their significant influence on shaping the methodological frameworks used in MANET disaster research. For instance, Indian institutions frequently focus on protocol optimization and resource management methodologies, contributing to improved energy efficiency and scalability in disaster communication systems. Similarly, the United States leads in research concerning security mechanisms and network reliability, offering advanced solutions for safeguarding MANETs in high-risk disaster scenarios. China's methodological focus often involves the development of routing algorithms and interoperability solutions, crucial for enhancing cross-network communication. These diverse methodological approaches have collectively advanced the robustness, scalability, and reliability of MANETs in disaster situations.

Figure 3 The top 15 countries and academic institutions that make the most publications.

South Korea holds the fifth position, with 87 total publications, and 77.01% of these publications are from single-country contributions. Kyungpook National University is the most productive academic institution in South Korea, with 12 publications. Like Japan, South Korea demonstrates a high level of domestic research collaboration.

Moving down the list, a range of countries with varying levels of total publications and percentages of SCPs is observed. The United Kingdom, Canada, Germany, Taiwan, and Pakistan demonstrate a mix of domestic and international collaborations. However, countries like Spain, France, Malaysia, Italy, and Saudi Arabia show lower percentages of SCPs, indicating a higher degree of international collaboration in their research endeavors. *Table 5* demonstrates the research productivity of various countries and academic institutions. It highlights the volume of publications and the extent of international collaborations for each country, shedding light on the global landscape of scholarly research.

Table 5 The top 15 countries and academic institutions that make the most publications

Rank	Country	TPc	S.C.P(%)	Most productive academic institutions	TPi
1.	India	444	92.57	Anna University	13
2.	United States	216	66.20	University of Illinois Urbana-Champaign	9
				University of California	9
3.	China	209	68.90	Beihang University	10
4.	Japan	175	81.14	Hiroshima City University	18
5.	South Korea	87	77.01	Kyungpook National University	12
6.	United Kingdom	83	45.78	Kingston University	8
7.	Canada	66	45.45	University of Victoria	5
8.	Germany	66	66.67	Technical University Ilmenau	16
9.	Taiwan	64	79.69	National Chiao Tung University	7
10.	Pakistan	56	39.29	National University of Sciences and Technology Pakistan	6
11.	Spain	51	23.53	Technical University of Valencia	3
12.	France	47	51.06	University of Technology of Compiègne	2
13.	Malaysia	46	52.17	Universiti Tenaga Nasional	5
14.	Italy	44	59.09	Sapienza University of Rome	9
15.	Saudi Arabia	36	25.0	Umm Al-Qura University	2

The arrangement of countries based on their respective continents is depicted in *Figure 4*. The link observed in VOSviewer between the two countries signifies a relationship between them, as evidenced by the proximity and thickness of the link. These characteristics indicate the extent of joint efforts in the field of MANET disaster research. The proximity between the two nations contributes to strengthening collaborative publishing, as the shorter distance facilitates closer relations between them. Likewise, an increase in line thickness corresponds to an elevation in the interconnectedness of the linkages. According to the data presented in *Figure 4*, the colour-coded items correspond to different regions worldwide. Specifically, the green things represent Asian countries, the red items symbolise Europe, the blue goods denote South America, the yellow items represent North America, the purple items signify Africa, and the sky-blue items indicate Oceania. Their respective continents can categorise the distribution of countries involved in the research area of MANET catastrophe as follows: Asia (28), Europe (27), South America (5), North America (4), Africa (10), and Oceania (2). Antarctica is not associated with any sovereign nations. Therefore, the colour of the item "Antarctica" was not depicted in *Figure 4.*

As illustrated in *Figure 4*, examining co-authorship patterns revealed that India held the most extensive affiliations, spanning connections with 49 countries and engaging in co-authorship 444 times. Following India, the United States demonstrated 108 links and 216 instances of co-authorship, while China exhibited 94 links and 209 cases of collaboration. Japan and South Korea followed suit with 43 links and 175 co-authorships and 24 and 87 co-authorships, respectively. Moreover, among the 76 countries included in the database, over 90% of them have contributed publications totalling less than 80 in collaboration with partners from other nations.

4.4Leading authors

Table 6 showcases the leading contributors to MANET disaster research. The data reveals that eight of the fifteen authors listed are affiliated with Japan, with the remaining authors representing nations including the United States, Germany, Sweden, the United Kingdom, France, and Spain. Notably, these authors predominantly serve as primary authors in the research articles, with their publication history dating back to 2000. Moreover, they greatly emphasise publishing research articles about MANET disasters. Consequently, most authors in *Table 6* have accumulated over 80 research articles collectively.

Among the 1745 MANET disaster research articles analysed, Gerla Mario from the United States contributed 26 articles. Notably, Gerla boasts the highest H-index of 88, underscoring his work's profound impact and influence within the realm of MANET disaster research. With a remarkable total of 952 publications and 27,610 citations, his contributions are extensive and widely recognised within the research community. Being affiliated with the University of California, Gerla will likely have access to state-of-the-art resources, which may have facilitated his research productivity and impact.

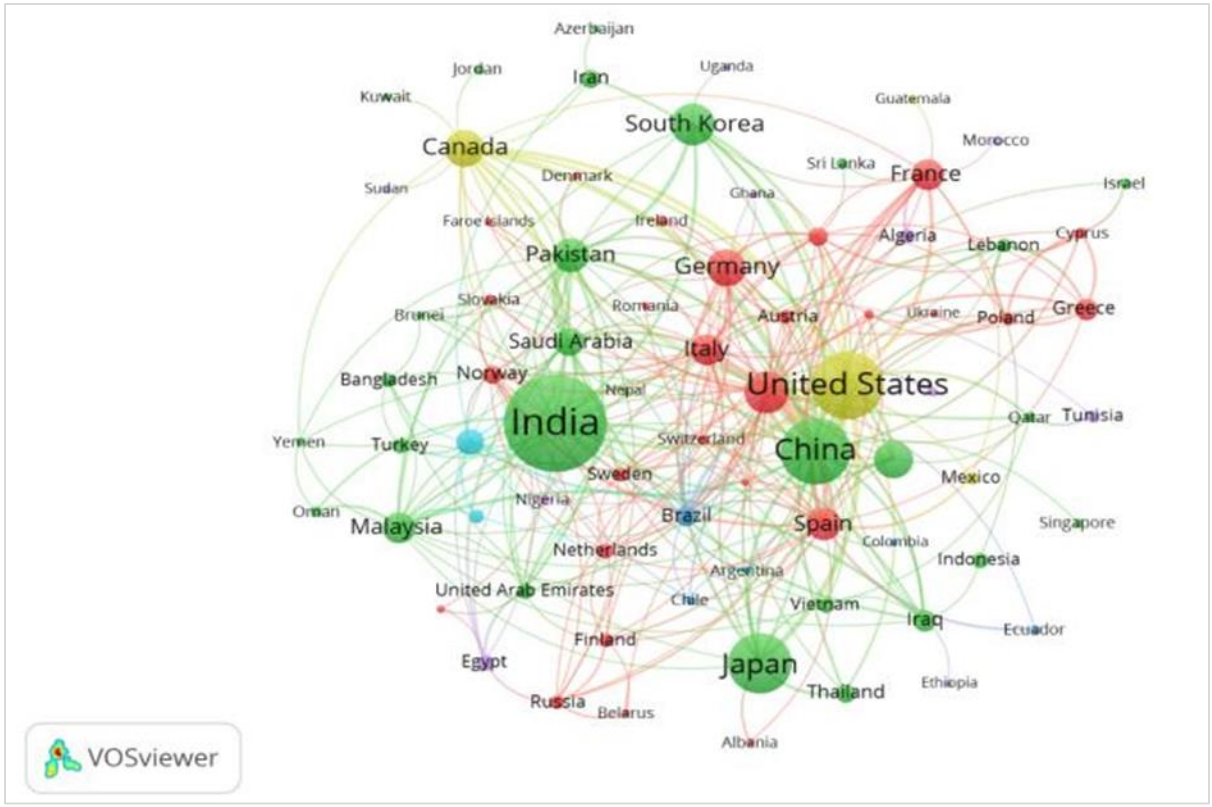

Figure 4 Co-authorship mapping in network visualisation mode

Table 6 List of the most prolific authors in the modern disaster research area

No.	Author	Scopus author ID	Year of 1st publication *	Total Publication (TP)	H-index	Total citation (TC)	Current affiliation	Country
1	Gerla, Mário	35552197100	2000[a]	952	88	27610	University of California	United States
2	Seitz, Jochen	23010266700	2011[a]	96	10	376	Technical University Ilmenau	Germany
3	Kakuda, Yoshiaki	7005630359	2007[b]	237	16	857	Hiroshima City University	Japan
4	Wada, Tomotaka	23010851100	2008[a]	88	12	304	Kansai University	Japan
5	Barolli, Leonard	6601911059	2005[a]	1437	45	4599	Fukuoka Institute of Technology	Japan
6	Krug, Silvia	56151713900	2014[a]	43	8	164	Mid Sweden University	Sweden
7	Ohta, Tomoyuki	7403162164	2007[b]	105	13	474	Hiroshima City University	Japan
8	Okada, Hiromi	35792591900	2000[a]	93	15	699	Kansai University	Japan
9	Ohtsuki, Kazuhiro	7102905866	2008[a]	51	6	149	Kansai University	Japan
10	Politis, Christos	7005376678	2009[a]	113	15	819	Kingston University	United Kingdom

No.	Author	Scopus author ID	Year of 1st publication *	Total Publication (TP)	H-index	Total citation (TC)	Current affiliation	Country
11	Schellenberg, Sebastian	55370692600	2013[a]	21	7	90	University of Erlangen–Nuremberg	Germany
12	Delot, Thierry	13907825900	2008[a]	66	13	421	Polytechnic University of Hauts-de-France	France
13	Ishii, Hiroshi	55226827900	2006[a]	118	11	1457	Tokai University	Japan
14	Kulla, Elis	36696753700	2012[a]	173	15	617	Fukuoka Institute of Technology	Japan
15	Gutiérrez-Reina, Daniel	36186039200	2011[a]	89	23	1220	University of Seville	Spain

Role in co-authorship, superscripts, [a] First author, [b] Co-author

Second place came to Seitz Jochen, who had 15 MANET disaster research articles. Although Seitz has a comparatively lower number of publications (96), his H-index of 10 suggests that his work has been cited more often than the average. With a current affiliation at the Technical University Ilmenau in Germany, Seitz's research is likely focused on specific aspects of MANET disaster research, contributing to his specialised expertise.

Kakuda Yoshiaki, Barolli Leonard, and Kulla Elis from Japan have contributed substantially to the field, with 237, 1437, and 173 publications, respectively. Kakuda's output of 237 papers stands out prominently among the listed authors. His work, accompanied by 857 total citations, has notably impacted the field. Being affiliated with Hiroshima City University, Kakuda might be involved in research related to disaster scenarios, considering the university's location and expertise in disaster management.

Meanwhile, Barolli stands out with an impressive number of publications (1,437), making him the most prolific author. His H-index of 45 and total citation count of 4,599 demonstrate the impact and influence of his research. Being affiliated with the Fukuoka Institute of Technology, Barolli likely has access to cutting-edge resources and collaborations that have fueled his research output. An intriguing aspect of *Table 6* is the inclusion of Gutiérrez-Reina, ranked fifteenth, who, despite this placement, boasts a noteworthy H-index of 23 and a substantial total citation count of 1220.

Gutiérrez-Reina has authored 89 research articles within 12 years, positioning him as one of the most prolific authors within a relatively brief timeframe. Overall, the authors listed in *Table 6* have made significant contributions to the field of MANET disaster research. Their H-index, publication count, citation count, and affiliations provide insights into their expertise and impact. These authors have dedicated their efforts to advancing the understanding and solutions for disaster scenarios in MANETs.

The analysis of the most prolific authors in MANET disaster research highlights these individuals' contributions, expertise, and impact in the field. Their extensive publication history, high H-indices, and significant citation counts demonstrate their influence on the research community. The affiliations of these authors also shed light on the geographical distribution of research in this field, with notable contributions from universities in the United States, Japan, and Germany. Their collective efforts have undoubtedly advanced the understanding and development of MANET disaster research, paving the way for improved solutions and strategies in disaster scenarios.

4.5Author keywords

Before commencing the analysis, an extraction process initially yielded 191 results. However, a thesaurus was utilised to refine the dataset to enhance relevance and mitigate redundancy. Consequently, from a total of 3459 author keywords, only 135 were selected for mapping in the VOSviewer software. This selection was facilitated by implementing relabelling techniques to consolidate synonymous and closely related terms while adhering to a minimum occurrence threshold set at the default value 5.

4.5.1Terminology and concept

The bibliometric map analysis illustrated in *Figure 5* reveals that the term " MANET " exhibits the highest occurrence frequency, totalling 455 instances. Additionally, it demonstrates 112 linkages to other keywords and a cumulative link strength of 678, establishing its prominence as the most prevalent keyword in the dataset. Following this, keywords such as "VANET" (394 occurrences, 107 links) and "ad hoc network" (219 occurrences, 87 links) trail behind in frequency. These keywords are pertinent to MANET disasters and recognised as pragmatic approaches deployed in scenarios where physical network infrastructures are inaccessible. Additionally, our findings unveil several keywords associated with analytical instruments utilised in exploring MANET disasters, such as " QoS " (66 occurrences, 50 links), "simulation" (27 occurrences, 21 links), "performance evaluation" (22 occurrences, 18 links), "optimisation" (14 occurrences, 19 links), "fuzzy logic" (12 occurrences, 14 links), and "performance analysis" (9 occurrences, 14 links).

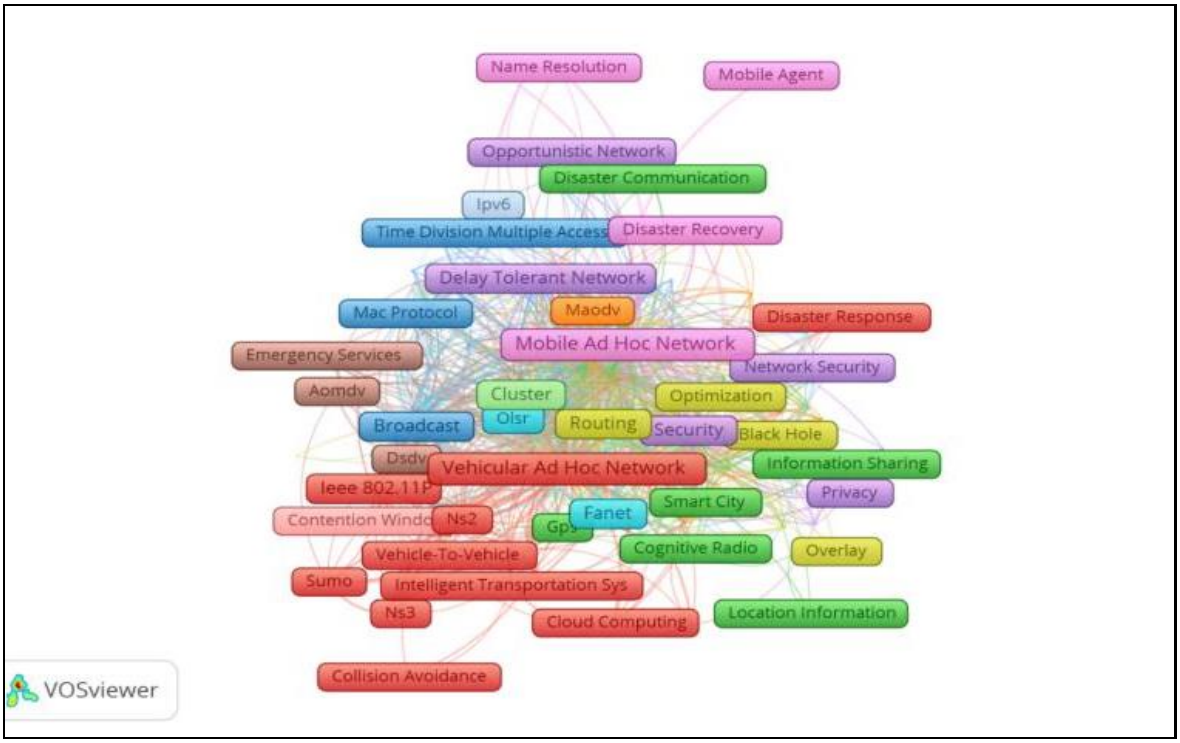

Figure 5 Network visualization of author keywords co-occurrence map for MANET disaster research (1997-2022)

Analysing the co-occurrence map of author keywords in overlay visualisation mode (*Figure 6*) reveals discernible trends, shedding light on emerging directions within the realm of MANET disasters. Noteworthy occurrences include "blockchain" and "machine learning" in 2021, "cluster head" and "reinforcement learning" in 2020, and "deep learning," "emergency vehicles," "fanet," "internet of things(IoT)," "internet of vehicles," "latency," " UAVs," "fog computing," and "smart city" in 2019. Concurrently, keywords such as "congestion," "drone," "energy," "network security," "software-defined networking," and "trust management" have been subjects of study since 2018.

These keywords highlight the exploration of advanced technologies and innovative approaches to enhance the capabilities of MANETs in disaster scenarios. Incorporating these technologies can improve communication, data dissemination, and emergency decision-making processes. Besides, the occurrences of keywords such as “blockchain” and “network security” suggest the significance of ensuring secure and trustworthy communication in disaster and emergency contexts. Robust authentication mechanisms and effective network security measures are crucial to safeguarding communication and protecting against potential threats and vulnerabilities.

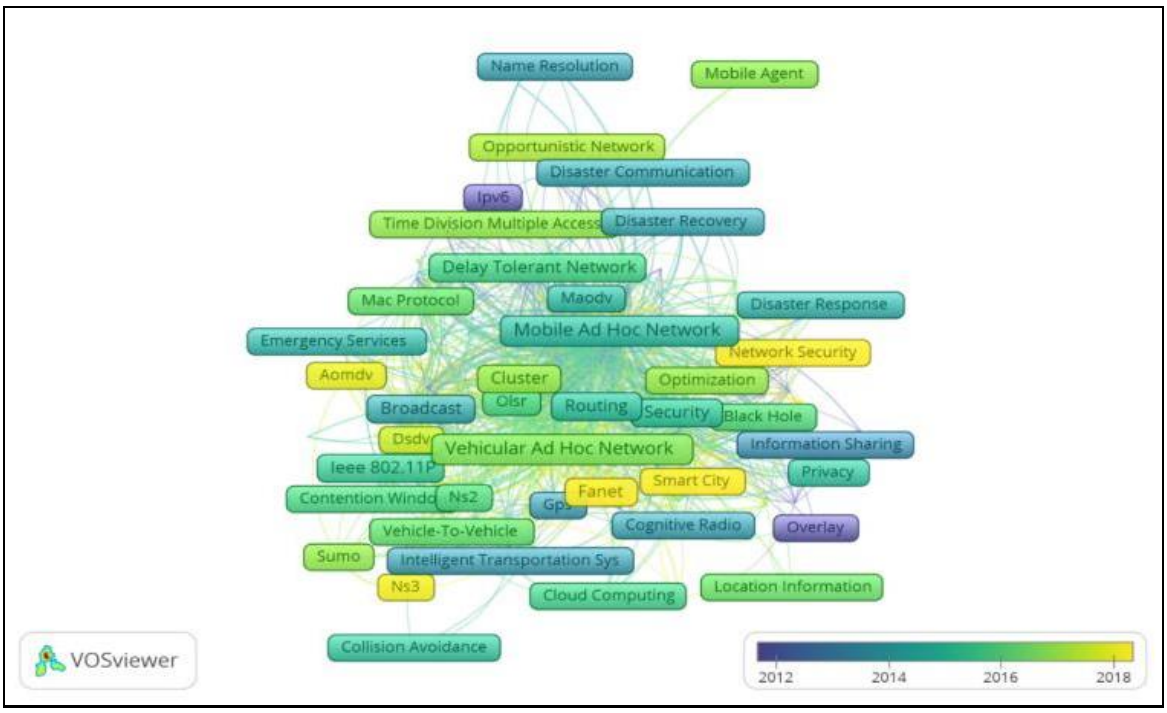

Figure 6 Overlay visualization of author keywords co-occurrence map for MANET disaster research (1997-2022)

The occurrences of keywords such as “congestion”, “energy”, and “latency” represent important aspects and challenges in MANET research related to disaster and emergency scenarios. Understanding emergency management strategies, optimising performance, evaluating routing protocols, and utilising wireless sensor networks are essential for effective communication and response in disaster situations.

The analysis of the co-occurrence of author keywords in MANET disaster and emergency research reveals the central themes and areas of focus in this field. Key topics include ad hoc networks, routing protocols, access control, security, emerging technologies, and disaster-related concepts. By exploring these keywords and their relationships, researchers can gain insights into the interconnectedness and significance of different aspects of MANETs in disaster and emergency scenarios. This analysis provides a foundation for further research and the development of innovative solutions to address the challenges and requirements of communication in such critical situations.

4.5.2Topics of interest

As depicted in *Figure 6*, the inception of "Deep learning" within MANET disaster publications began in 2019. This term has attracted attention among researchers, demonstrating growth with 6 occurrences and 5 links within a mere 4-year period. Likewise, "Machine learning," with 4 occurrences and 5 links, emerged in 2021. Both terms are interrelated, with deep learning under the umbrella of machine learning operating within AI. In recent years, the application of deep learning algorithms in various research domains, notably MANET disaster databases, has witnessed significant progress in developing and refining novel techniques, architectures, and applications. Analysing and processing such data poses challenges, as it involves handling large datasets and extracting intricate patterns and relationships. Consequently, deep learning algorithms effectively learn from unstructured MANET disaster data, often yielding notable outcomes. These algorithms can be trained using diverse datasets, achieving high event detection and classification accuracy.

Besides that, we can see that MANETs and other ad hoc networks are still relevant for further research, especially in disaster scenarios. Many sub-fields are being explored yearly to improve the network performance for disaster management. *Figure 6* shows that in 2018 and onwards, other research fields, such as blockchain. [51–54], cluster head [55–57], energy [3, 41, 58], emergency vehicles [9, 44], [59–61], smart city [62, 63], and Ns3 [64, 65] Have been grabbing the attention of researchers. The terms

"Blockchain" has 8 occurrences and 9 links started in 2021, "Cluster head" has 6 occurrences and 5 links, "Energy" has 10 occurrences and 13 links, "Emergency vehicles" has 7 occurrences and 8 links, "Smart city" has 14 occurrences and 21 links. Lastly, the term "Ns3" has 8 occurrences and 8 links.

The terms have shown interest among researchers and have grown throughout the years, despite the exploration in such sub-fields starting in 2018 and onwards. Further research in this field will have a broader impact on the research community with the hope that it can improve the MANET's communication capabilities in disaster scenarios, enabling effective coordination, information dissemination, and rescue operations.

In conclusion, the bibliometric analysis of MANETs related to disaster and emergency studies has provided valuable insights into this critical research area's prevalent topics, research trends, and interdisciplinary aspects. The challenges and gaps in knowledge presented ample opportunities for further investigation and innovation, aiming to develop resilient, secure, and efficient communication solutions to support disaster response and emergency management efforts.

4.6The distribution of MANET disaster contributors and their directions

As illustrated in *Figure 5*, a co-occurrence author keywords map unveils a significant correlation between the volume of research articles and their central and sub-themes. Notably, the top two sub-themes identified are " MANET " and "VANET," encompassing 752 and 562 research articles. *Figure 7* portrays the top four contributors to MANET disasters and their associated themes. *Figure 7(a)* delineates four items as contributors to MANET disasters: MANET, ad hoc network, mobile telecommunication systems, and disasters. *Figure 7(b)* lists VANETs, vehicles, ad hoc networks, and vehicle-to-vehicle communication as significant contributors. Overall, the research trajectory depicted by the MANET disaster contributors and new directions graphs indicates a consistent upward trend from 1997 to 2022.

In 2010, the item "ad hoc network" for both sub-themes showed a drastic increase from the previous year. The item decreased drastically for 5 years onwards. From *Figure 7*, it can be seen that the researchers are showing a positive interest towards the directions related to the sub-themes. The items of "MANET" and "VANET" had a positive increase of interest in 2010 and onwards. These can be influenced by the rise of the item "ad hoc network". To conclude, "MANET" and "VANET" are part of an ad hoc network.

Figure 8 demonstrates that India leads in research articles among sub-themes related to MANET disasters. The variation in the number of research articles among sub-themes and their respective directions is minimal, with " MANET " (215), "ad hoc network" (131), "mobile telecommunication systems" (83), and "disasters" (83). Notably, in five nations (the United States, China, Japan, South Korea, and the United Kingdom), the publication count regarding "mobile telecommunication systems" and "disasters" exhibits minimal variation.

Furthermore, *Figure 9* delineates the second highest sub-theme regarding published articles related to MANET disasters, namely "VANET." India emerges as the primary contributor across all four topics associated with VANETs: "VANET" (151), "vehicles" (53), "ad hoc network" (126), and "vehicle-to-vehicle communication" (36). China follows closely as the second highest contributor for the topics "VANET" (101) and "ad hoc network" (120).

4.7Methodological trends in MANET disaster research

Based on an analysis of the most frequently used methodologies in MANET disaster research, several trends can be observed, with simulation emerging as the most prominent technique, followed by a rising interest in AI and optimization methods.

The author's keyword "simulation" [46, 66–70] with 27 occurrences, is frequently employed to test the performance and scalability of MANETs under disaster scenarios. It allows researchers to replicate real-world conditions like congestion, energy efficiency, and network reliability, helping identify potential improvements. Meanwhile, the keyword "fuzzy logic" [71–74] with 12 occurrences, is used in decision-making processes within MANETs, particularly in dynamic routing and energy efficiency, providing flexibility in dealing with uncertain and imprecise data.

The author's keywords, "machine learning" [75–79] and "deep learning" [80–84] with 5 occurrences each, are gaining attention for their potential to enhance the predictive capabilities of the MANETs. They are applied to optimize routing protocols and improve

security mechanisms by detecting anomalies in the network. The author's keyword "genetic algorithms" [85–88] with 5 occurrences, is employed for network optimization, particularly in areas like load balancing and energy-efficient routing. They help in identifying optimal paths within dynamic and constrained networks.

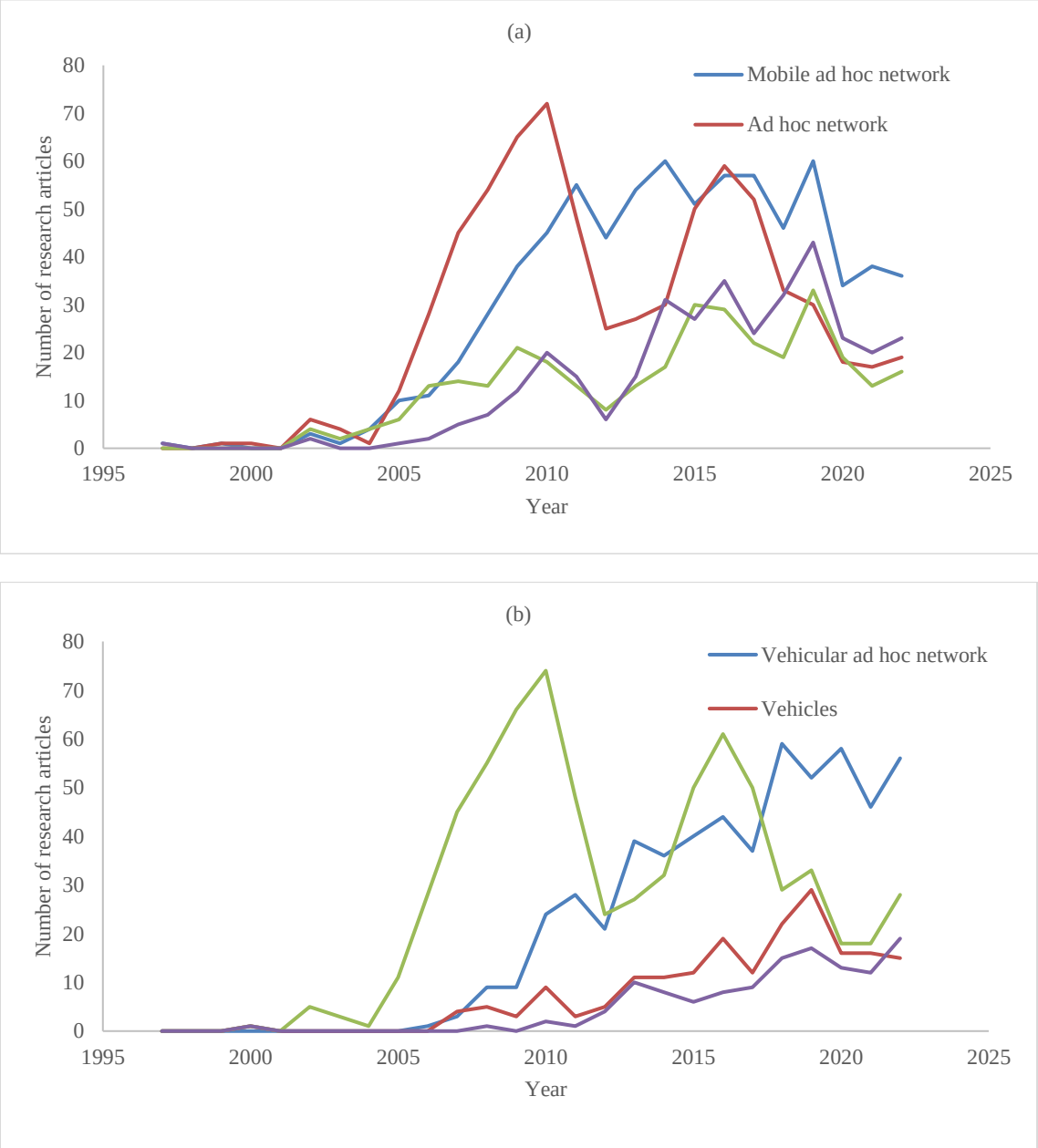

Figure 7 Research trends of selected contributors (a) MANET and (b) VANET in MANET disaster research (1997-2022)

Figure 10 provides a visual representation of the frequency of these methodologies based on keyword occurrences, highlighting the prevalence of simulation as a core research method.

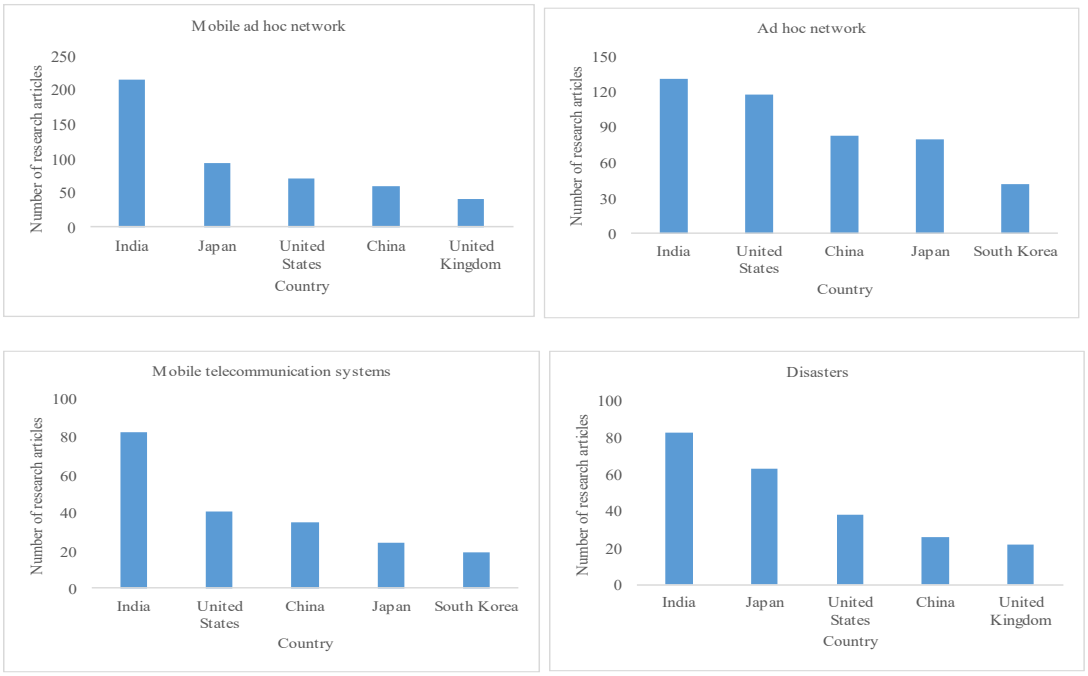

Figure 8 Top five countries with most published articles on "MANET" sub-theme in MANET disaster research (1997-2022)

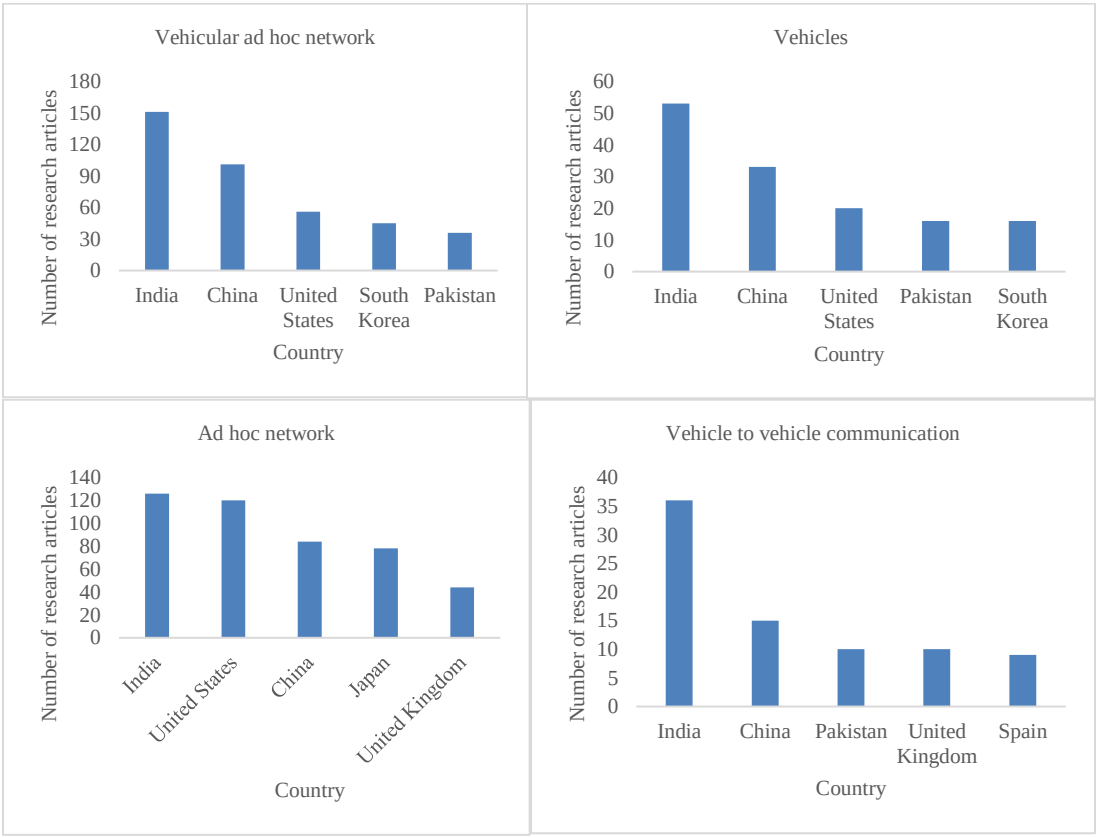

Figure 9 Top five countries with most published articles on "VANET" sub-theme in MANET disaster research (1997-2022)

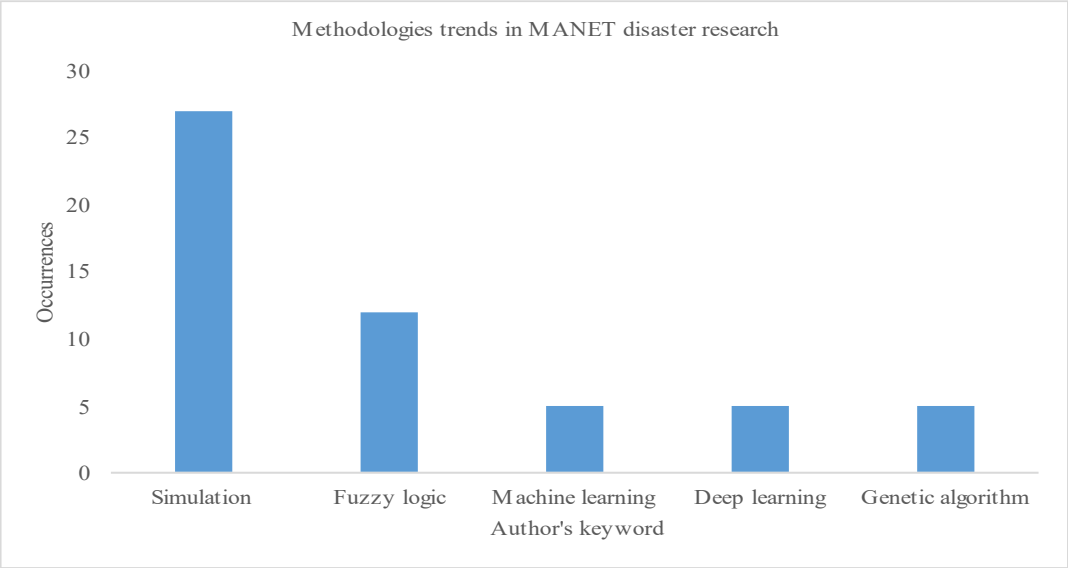

Figure 10 Frequency of methodologies in MANET disaster research (1997–2022)

4.8Limitations

The study's limitations stem from several factors that could impact the comprehensiveness of the findings. Firstly, the search parameters were confined to titles and abstracts in the Scopus database using specific terms such as "disaster," "emergency," "MANET," and "ad hoc network." This restriction may result in incomplete coverage of relevant articles on MANET-related disasters due to variations in researchers' terminologies, which can lead to potential oversights. Additionally, the search results are subject to change based on the search date due to Scopus's ongoing database updates.

Another limitation is the focus on a specific time frame, from 1977 to 2022, which excludes the most recent publications from 2023 onward. The analysis was restricted to the Scopus database, potentially introducing bias as other databases like WoS and Google Scholar were not considered. Each database has its indexing criteria and scope, which could affect the breadth of the literature reviewed. Furthermore, the study exclusively employed the VOSviewer tool for co-occurrence analysis, neglecting other potentially valuable data extraction and analysis tools.

A complete list of abbreviations is listed in *Appendix I.*

5. Conclusion and future work

This study comprehensively examines the evolution and trajectories of MANET disaster research trends from 1997 to 2022, leveraging the Scopus database and encompassing 1745 papers published in reputable journals. The methodology commenced by excluding irrelevant review articles during the initial data collection phase. Subsequently, the VOSviewer software was utilised to generate various visual representations of the textual content. Additionally, tables tabulating the most productive journals and authors were structured following the layout prescribed by the Scopus website. Over the period from 1997 to 2022, the indexing of MANET disasters in Scopus demonstrated notable dependence on terms such as MANET, VANET, and ad hoc network, with occasional spikes observed in specific years. Based on the observed trend, a continuous increase in research interest in MANET disasters is anticipated in the foreseeable future.

The findings of this bibliometric analysis have significant implications for both research and practice in the field of disaster communication. The increasing focus on MANETs for disaster scenarios reveals their potential as a critical tool for maintaining communication when traditional infrastructures fail. One of the key advantages of MANETs is their ability to provide scalable and flexible communication networks that can be rapidly deployed in disaster zones [5]. This flexibility is particularly important in scenarios where communication infrastructures are damaged or non-existent, offering a lifeline for first responders and coordination teams during emergencies.

However, several challenges remain. MANETs often struggle with issues of energy efficiency [24, 29], as nodes are typically battery-powered, requiring the development of energy-efficient protocols to ensure sustained network operation. Additionally, security vulnerabilities [20, 23] pose a significant concern, particularly in high-risk environments where data breaches, denial-of-service attacks, and unauthorized access can severely compromise disaster management efforts. Future research must focus on overcoming these challenges by developing more robust, secure, and energy-efficient solutions. As this analysis shows, countries like the United States and China are at the forefront of addressing these challenges, offering valuable methodologies for network reliability and interoperability in disaster situations. Overall, while MANETs hold immense potential for disaster management, ongoing research and innovation are essential to fully realize their effectiveness in real-world applications [5].

Furthermore, the study discerned those countries or institutions from India, the United States, China, Japan, and South Korea have emerged as the primary contributors to published articles, collectively accounting for over 50% of the SCP. Factors such as international collaboration, expertise, and robust infrastructural facilities were identified as significant contributors to countries' high publication outputs. Finally, the study delineated various research directions associated with MANET disasters. It was observed that keywords such as "MANET," "VANET," and "ad hoc network" constituted the most prevalent contributors to MANET disasters. Concurrently, recent years have witnessed a focus on keywords including "blockchain," "machine learning," "cluster head," "reinforcement learning," "deep learning," "emergency vehicles," "fanet," " IoT," "internet of vehicles," "latency," " UAVs," "fog computing," and "smart city." This study aims to serve as a valuable resource for scholars exploring new avenues of research, recognising that continuous advancements can be made to enhance network communication performance, particularly in disaster scenarios.

MANETs present a promising approach to disaster management, offering essential communication infrastructure in situations where traditional networks fail. Despite their potential, several challenges must be overcome to maximise their effectiveness, including scalability, energy efficiency, and security issues. This study has highlighted key trends and identified gaps in current research, establishing a foundation for future investigations.

To enhance the study's informativeness, this research proposes integrating AI and ML tools to identify future trends in MANET disaster research. AI techniques such as natural language processing (NLP) can be utilised to analyse large volumes of academic publications and extract meaningful patterns and insights. Machine learning algorithms, particularly those focused on trend prediction, can help identify emerging research areas, gaps, and potential collaborations. Incorporating AIML approaches can provide a more dynamic and forward-looking analysis, enhancing our understanding of how MANETs can be optimised for use in disaster management scenarios.

Future research should prioritise the development of more robust MANET protocols, integrating emerging technologies such as fifth-Generation (5G) and the IoT to enhance network capabilities. Additionally, expanding the scope of analysis to include economic factors and user behaviour will provide a more comprehensive understanding of MANET applications and effectiveness. To address limitations and reduce selection bias, future studies should also consider incorporating additional databases, such as WoS and Google Scholar, thereby broadening the research scope and improving the overall depth of analysis.

Acknowledgment

This research was supported by the Fundamental Research Grant Scheme (FRGS/1/2021/ICT11/UNISZA/02/1) under the Ministry of Higher Education (MOHE) and Universiti Sultan Zainal Abidin (UniSZA), Malaysia.

Conflicts of interest

The authors have no conflicts of interest to declare.

Data availability

None.

Author's contribution statement

Fatin Fazain Mohd Affandi: Conceptualization, writing-original draft preparation, methodology, software, visualisation formal analysis, writing-reviewing-editing and validation. **Nor Aida Mahiddin:** Supervision, validation, writing-reviewing-editing and funding acquisition. **Zarina Mohamad:** Supervision, validation, writing-reviewing-editing and funding acquisition. **Nurul I. Sarkar:** Supervision, validation, and writing-reviewing-editing.

References

[1] Aardal KI, Van HSP, Koster AM, Mannino C, Sassano A. Models and solution techniques for frequency assignment problems. Annals of Operations Research. 2007; 153:79-129.

[2] Zakaria AH, Saman MY, Noor AS, Hassan H. Finding shortest routing solution in mobile ad hoc networks using firefly algorithm and queuing network analysis. Jurnal Teknologi. 2015; 77(18):17-22.

[3] Kniess J, Petri M, Parpinelli RS. An energy-efficient bio-scheduling model for emergency networks. In IEEE wireless communications and networking conference 2021 (pp. 1-6). IEEE.

[4] Walunjkar G, Rao AK. Simulation and evaluation of different mobility models in disaster scenarios. In 4th international conference on recent trends on electronics, information, communication & technology 2019 (pp. 464-9). IEEE.

[5] Affandi FF, Mahiddin NA, Mohamad Z. DRT mobility model for search and rescue operations based on catastrophic intensity to improve the quality of services. International Journal of Advanced Technology and Engineering Exploration. 2024; 11(112):332-53.

[6] Kwon Y, Song J. System-reliability-based disaster resilience analysis of infrastructure networks and causality-based importance measure. ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part B: Mechanical Engineering. 2023; 9(3):1-22.

[7] Kirby A. Exploratory bibliometrics: using VOSviewer as a preliminary research tool. Publications. 2023; 11(1):1-14.

[8] Moral-muñoz JA, López-herrera AG, Herrera-viedma E, Cobo MJ. Science mapping analysis software tools: a review. Springer Handbook of Science and Technology Indicators. 2019:159-85.

[9] Bhatia TK, Ramachandran RK, Doss R, Pan L. Data congestion in VANETs: research directions and new trends through a bibliometric analysis. The Journal of Supercomputing. 2021; 77:6586-628.

[10] Martín-martín A, Orduna-malea E, Thelwall M, López-cózar ED. Google scholar, web of science, and scopus: a systematic comparison of citations in 252 subject categories. Journal of Informetrics. 2018; 12(4):1160-77.

[11] Vieira ES, Gomes JA. A comparison of Scopus and web of science for a typical university. Scientometrics. 2009; 81:587-600.

[12] Mishra D, Gunasekaran A, Papadopoulos T, Childe SJ. Big data and supply chain management: a review and bibliometric analysis. Annals of Operations Research. 2018; 270:313-36.

[13] https://www.vosviewer.com/. Accessed 23 May 2023.

[14] Van ENJ, Waltman L, Dekker R, Van DBJ. A comparison of two techniques for bibliometric mapping: multidimensional scaling and VOS. Journal of the American Society for Information Science and Technology. 2010; 61(12):2405-16.

[15] Klavans R, Boyack KW. Toward a consensus map of science. Journal of the American Society for Information Science and Technology. 2009; 60(3):455-76.

[16] Van EN, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010; 84(2):523-38.

[17] Newman ME. Coauthorship networks and patterns of scientific collaboration. Proceedings of the National Academy of Sciences. 2004; 101(suppl_1):5200-5.

[18] Wang CH, Lin CC, Lee Y, Kuo JH. Mapping the intellectual structure of mobile ad hoc networks. Advances in Information Sciences and Service Sciences. 2012; 4(1): 432-441.

[19] Liang W, Li Z, Zhang H, Wang S, Bie R. Vehicular ad hoc networks: architectures, research issues, methodologies, challenges, and trends. International Journal of Distributed Sensor Networks. 2015; 11(8):1-11.

[20] Sumra IA, Sellappan P, Abdullah A, Ali A. Security issues and challenges in MANET-VANET-FANET: a survey. EAI Endorsed Transactions on Energy Web. 2018; 5(17):1-6.

[21] Gupta R, Patel P. A survey on vehicular ad hoc networks. International Journal of Scientific Research in Science, Engineering and Technology. 2016; 15(4):34-42.

[22] Lee M, Atkison T. VANET applications: past, present, and future. Vehicular Communications. 2021; 28:100310.

[23] Rodríguez-baeza JA, Magán-carrión R, Ruiz-villalobos P. Advances on security in ad hoc networks: a preliminary analysis. In 16th Iberian conference on information systems and technologies 2021 (pp. 1-5). IEEE.

[24] Aldana JA, Maag S, Zaïdi F. MANETs interoperability: current trends and open research. IIn 32d international conference on advanced information networking and applications workshops 2018 (pp. 481-7). IEEE.

[25] Fratta L, Gerla M, Lim KW. Emerging trends and applications in ad hoc networks. Annals of Telecommunications. 2018; 73:547-8.

[26] Cavalcanti ER, De SJA, Spohn MA, Gomes RC, Costa AF. VANETs' research over the past decade: overview, credibility, and trends. ACM SIGCOMM Computer Communication Review. 2018; 48(2):31-9.

[27] Mahi MJ, Chaki S, Ahmed S, Biswas M, Kaiser MS, Islam MS, et al. A review on VANET research: perspective of recent emerging technologies. IEEE Access. 2022; 10:65760-83.

[28] Sanchezl LC, Parra OJS, Rico MJE. The evolution of VANET networks: a review of emerging trends in artificial intelligence and software-defined networks. Computer Science & Information Technology (CS & IT). 2023; 13(22):209-19.

[29] Dalal R, Khari M, Misra S. Speculative analysis of wireless network by bibliometrics tool. Wireless Personal Communications. 2024; 135:2039-59.

[30] Xie F, Hua KA, Wang W, Ho YH. Performance study of live video streaming over highway vehicular ad hoc networks. In 66th vehicular technology conference 2007 (pp. 2121-5). IEEE.
[31] Zhu H, Lin X, Lu R, Ho PH, Shen X. AEMA: an aggregated emergency message authentication scheme for enhancing the security of vehicular ad hoc networks. In international conference on communications 2008 (pp. 1436-40). IEEE.
[32] Gerla M, Zhou B, Lee YZ, Soldo F, Lee U, Marfia G. Vehicular grid communications: the role of the internet infrastructure. In proceedings of the 2nd annual international workshop on wireless internet 2006. ACM.
[33] Sumayya PA, Shefeena PS. VANET based vehicle tracking module for safe and efficient road transportation system. Procedia Computer Science. 2015; 46:1173-80.
[34] Rajput NS, Banerjee R, Siwach A, Rajput A. e-ARP: an efficient, adaptive and robust protocol for effective data communication in VANETs. In TENCON IEEE region 10 conference 2017 (pp. 1263-8). IEEE.
[35] Yang Q, Shen L. A multi-hop broadcast scheme for propagation of emergency messages in VANET. In 12th international conference on communication technology 2010 (pp. 1072-5). IEEE.
[36] Liu J, Yang Z, Stojmenovic I. Receiver consensus: on-time warning delivery for vehicular ad-hoc networks. IEEE Transactions on Emerging Topics in Computing. 2013; 1(1):57-68.
[37] Al-tekreeti S, Adams C, Al-jawad N. Creating Wi-Fi bluetooth mesh network for crisis management applications. In mobile multimedia/image processing, security, and applications 2010 (pp. 325-36). SPIE.
[38] Ramrekha TA, Millar GP, Politis C. A model for designing scalable and efficient adaptive routing approaches in emergency ad hoc communications. In symposium on computers and communications 2011 (pp. 916-23). IEEE.
[39] Steere DC, Baptista A, Mcnamee D, Pu C, Walpole J. Research challenges in environmental observation and forecasting systems. In proceedings of the 6th annual international conference on mobile computing and networking 2000 (pp. 292-9). ACM.
[40] Deng DJ, Chen HC, Chao HC, Huang YM. A collision alleviation scheme for IEEE 802.11 p VANETs. Wireless Personal Communications. 2011; 56:371-83.
[41] Jha A, Vivek V, Gupta P, Joshi R, Singh P, Iyengar NC. Trust aware secure energy efficient hybrid protocol for MANET. In international conference on artificial intelligence and smart communication 2023 (pp. 1105-9). IEEE.
[42] Tan S, Li X, Dong Q. Trust based routing mechanism for securing OSLR-based MANET. Ad Hoc Networks. 2015; 30:84-98.
[43] Mase K. Information and communication technology and electric vehicles–paving the way towards a smart community. IEICE Transactions on Communications. 2012; 95(6):1902-10.
[44] Benkerdagh S, Duvallet C. Cluster-based emergency message dissemination strategy for VANET using V2V communication. International Journal of Communication Systems. 2019; 32(5):e3897.
[45] Farooq W, Ali KM, Rehman S. A novel real time framework for cluster based multicast communication in vehicular ad hoc networks. International Journal of Distributed Sensor Networks. 2016; 12(4):8064908.
[46] Martinez FJ, Toh CK, Cano JC, Calafate CT, Manzoni P. A survey and comparative study of simulators for vehicular ad hoc networks (VANETs). Wireless Communications and Mobile Computing. 2011; 11(7):813-28.
[47] Bi Y, Shan H, Shen XS, Wang N, Zhao H. A multi-hop broadcast protocol for emergency message dissemination in urban vehicular ad hoc networks. IEEE Transactions on Intelligent Transportation Systems. 2015; 17(3):736-50.
[48] Chandrasekharamenon NP, AnchareV B. Connectivity analysis of one-dimensional vehicular ad hoc networks in fading channels. EURASIP Journal on Wireless Communications and Networking. 2012; 2012:1-6.
[49] Narayana VL, Bharathi CR. Identity based cryptography for mobile ad hoc networks. Journal of Theoretical and Applied Information Technology. 2017; 95(5):1173-81.
[50] Glänzel W, Schubert A. Analysing scientific networks through co-authorship. In handbook of quantitative science and technology research: the use of publication and patent statistics in studies of S&T systems 2004 (pp. 257-76). Dordrecht: Springer Netherlands.
[51] Ran C, Yan S, Huang L, Zhang L. An improved AODV routing security algorithm based on blockchain technology in ad hoc network. EURASIP Journal on Wireless Communications and Networking. 2021; 2021(1):1-16.
[52] Panda SK, Jena AK, Swain SK, Satapathy SC. Blockchain technology: applications and challenges. Cham: Springer International Publishing. 2021.
[53] Zamri N, Mohamad Z, Nik WN, Mohamad AH. Smart secure telerehabilitation apps for personalized autism home intervention using blockchain system. Blockchain for 5G-Enabled IoT: The New Wave for Industrial Automation. 2021:377-98.
[54] Li X, Jiang P, Chen T, Luo X, Wen Q. A survey on the security of blockchain systems. Future Generation Computer Systems. 2020; 107:841-53.
[55] Rajeswari AR, Lai WC, Kavitha C, Balasubramanian PK, Srividhya SR. A trust-based secure neuro fuzzy clustering technique for mobile ad hoc networks. Electronics. 2023; 12(2):1-16.
[56] Bharti M, Rani S, Singh P. Efficient cluster head selection and trust based routing in MANET. In journal of physics: conference series 2022 (pp. 1-8). IOP Publishing.
[57] Ramya R, Brindha T. A comprehensive review on optimal cluster head selection in WSN-IOT. Advances in Engineering Software. 2022; 171:103170.

[58] Muzakkari BA, Mohamed MA, Kadir MF, Mohamad Z, Jamil N. Recent advances in energy efficient-QoS aware MAC protocols for wireless sensor networks. International Journal of Advanced Computer Research. 2018; 8(38):212-28.
[59] Damaj I, Al KSK, Naous T, Lawand W, Abdelrazzak ZZ, Mouftah HT. Intelligent transportation systems: a survey on modern hardware devices for the era of machine learning. Journal of King Saud University-Computer and Information Sciences. 2022; 34(8):5921-42.
[60] Himawan H, Hassan A, Bahaman NA. A systematic literature review: intelligent vehicular communication system on VANET. International Journal of Mechanical Engineering. 2022; 7(2):212-29.
[61] Lozano DJM, Mateo STJ. Review on v2x, i2x, and p2x communications and their applications: a comprehensive analysis over time. Sensors. 2019; 19(12):1-29.
[62] Rejeb A, Rejeb K, Simske S, Treiblmaier H, Zailani S. The big picture on the internet of things and the smart city: a review of what we know and what we need to know. Internet of Things. 2022; 19:100565.
[63] Zhao F, Fashola OI, Olarewaju TI, Onwumere I. Smart city research: a holistic and state-of-the-art literature review. Cities. 2021; 119:103406.
[64] Nwuku YE, Ajibesin AA, Ishaq AT, Abel A. A comprehensive analysis of proactive and reactive MANET routing protocols using Ns3. Journal of Engineering and Applied Sciences Technology. 2021; 3(1):1-6.
[65] Zagrouba R, Kardi A. Comparative study of energy efficient routing techniques in wireless sensor networks. Information. 2021; 12(1):1-28.
[66] Viswanath K, Obraczka K, Tsudik G. Exploring mesh and tree-based multicast routing protocols for MANETs. IEEE Transactions on Mobile Computing. 2005; 5(1):28-42.
[67] Alazawi Z, Alani O, Abdljabar MB, Altowaijri S, Mehmood R. A smart disaster management system for future cities. In proceedings of the international workshop on wireless and mobile technologies for smart cities 2014 (pp. 1-10). ACM.
[68] Garcia-santiago A, Castaneda-camacho J, Guerrero-castellanos JF, Mino-aguilar G. Evaluation of AODV and DSDV routing protocols for a FANET: further results towards robotic vehicle networks. In 9th Latin American symposium on circuits & systems 2018 (pp. 1-4). IEEE.
[69] Chenchen Y, Xiaohong L, Dafang Z. An obstacle avoidance mobility model. In international conference on intelligent computing and intelligent systems 2010 (pp. 130-4). IEEE.
[70] Nelson SC, Harris IIIAF, Kravets R. Event-driven, role-based mobility in disaster recovery networks. In proceedings of the second workshop on challenged networks 2007 (pp. 27-34). ACM.
[71] Arulkumaran G, Gnanamurthy RK. Fuzzy trust approach for detecting black hole attack in mobile adhoc network. Mobile Networks and Applications. 2019; 24:386-93.
[72] Mehta K, Bajaj PR, Malik LG. Fuzzy bacterial foraging optimization zone based routing (FBFOZBR) protocol for VANET. In international conference on ICT in business industry & government 2016 (pp. 1-10). IEEE.
[73] Jadhav RS, Dongre MM, Devurkar G. Fuzzy logic based data dissemination in vehicular ad hoc networks. In international conference of electronics, communication and aerospace technology 2017 (pp. 479-83). IEEE.
[74] Kulla E, Spaho E, Xhafa F, Barolli L, Takizawa M. Using data replication for improving QoS in MANETs. In seventh international conference on broadband, wireless computing, communication and applications 2012 (pp. 529-33). IEEE.
[75] Sengan S, Khalaf OI, Rao GR, Sharma DK, Amarendra K, Hamad AA. Security-aware routing on wireless communication for E-health records monitoring using machine learning. International Journal of Reliable and Quality E-Healthcare. 2022; 11(3):1-10.
[76] Almalki FA, Angelides MC. Deployment of an aerial platform system for rapid restoration of communications links after a disaster: a machine learning approach. Computing. 2020; 102(4):829-64.
[77] Yoo SJ, Choi SH. Indoor AR navigation and emergency evacuation system based on machine learning and IoT technologies. IEEE Internet of Things Journal. 2022; 9(21):20853-68.
[78] Nazar K, Saeed Y, Ali A, Algarni AD, Soliman NF, Ateya AA, et al. Towards intelligent zone-based content pre-caching approach in VANET for congestion control. Sensors. 2022; 22(23):1-29.
[79] Ashtaiwi A. ML-based localizing and driving direction estimation system for vehicular networks. In international conference on artificial intelligence in information and communication 2021 (pp. 465-70). IEEE.
[80] Feng F, Liu X, Yong B, Zhou R, Zhou Q. Anomaly detection in ad-hoc networks based on deep learning model: a plug and play device. Ad Hoc Networks. 2019; 84:82-9.
[81] Lee Y. Classification of node degree based on deep learning and routing method applied for virtual route assignment. Ad Hoc Networks. 2017; 58:70-85.
[82] Chemodanov D, Esposito F, Sukhov A, Calyam P, Trinh H, Oraibi Z. AGRA: AI-augmented geographic routing approach for IoT-based incident-supporting applications. Future Generation Computer Systems. 2019; 92:1051-65.
[83] Yu Y, Zeng X, Xue X, Ma J. LSTM-based intrusion detection system for VANETs: a time series classification approach to false message detection. IEEE Transactions on Intelligent Transportation Systems. 2022; 23(12):23906-18.
[84] Nishi M, Kozato H, Ota Y, Shin K. Development of disaster monitoring techniques in the grass-root information distribution system for detecting landslide

dangers. In SmartWorld, ubiquitous intelligence & computing, advanced & trusted computing, scalable computing & communications, cloud & big data computing, internet of people and smart city innovation 2018 (pp. 1599-604). IEEE.
[85] Reina DG, Toral SL, Leon-coca JM, Barrero F, Bessis N, Asimakopoulou E. An evolutionary computational approach for optimizing broadcasting in disaster response scenarios. In seventh international conference on innovative mobile and internet services in ubiquitous computing 2013 (pp. 94-100). IEEE.
[86] Preetha V, Chitra K. Prediction of stability of the clusters in MANET using genetic algorithm. In international conference on advances in computer applications 2016 (pp. 338-41). IEEE.
[87] Wang J, Matsumoto K, Cheng Z, Zhou Y. A location optimization method based on communication requirements to reconnect separated communication areas after a disaster. In international conference on green computing and communications and IEEE internet of things and IEEE Cyber, physical and social computing 2013 (pp. 653-7). IEEE.
[88] Viswacheda DV, Arifranto MS, Hamid MY, Barukang L. QOS of efficient GA-EMAN routing method for future mobile tele-emergency system. In international conference on intelligent and advanced systems 2007 (pp. 378-82). IEEE.

Fatin Fazain Mohd Affandi was born in Kuala Terengganu, Terengganu, Malaysia in 1996. She received her B.S. Degree in Network Security and M.S in computer science from Universiti Sultan Zainal Abidin (UniSZA) in 2019 and 2023, respectively. Her research interests are Network Design, Modelling and Performance Evaluation, Ad Hoc Networks, and Security.
Email: fatinfazain@gmail.com

Nor Aida Mahiddin is currently a Fellow researcher at the East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin (UniSZA). She received a B.S. Degree in Information Technology from the National University of Malaysia, a Master's Degree in Computer Science, a major in Distributed Computing and a Ph.D. degree in Computer and Information Sciences from Auckland University of Technology, New Zealand. Dr. Nor Aida is a lecturer at the Faculty of Informatics and Computing, University Sultan Zainal Abidin (UniSZA), Malaysia. She is the author of several papers in peer-reviewed journals and conferences. She is a member of the Institute of Electrical and Electronics Engineers (IEEE), the Internet Society and The Society of Digital Information and Wireless Communications (SDIWC). Her research interests include Network Design, Modelling and Performance Evaluation, Wireless Communication Networks, Disaster Resilient Network Design, Optimisation of Gateway Congestion Control, Ad Hoc and Sensor Networks and Wireless Mesh and Routing Protocols.
Email: aidamahiddin@unisza.edu.my

Zarina Mohamad was born in Kuala Terengganu, Terengganu, Malaysia in 1972. She received her B.S. and M.S. degrees in computer science in 2000 and 2004, respectively. In 2013, she received her PhD from Universiti Tun Hussien Onn Malaysia. She is currently a senior lecturer in the Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin (UniSZA), Terengganu, Malaysia. Her research interests are Distributed Databases, Data Grids, Distributed Systems, Cloud Computing and Optimisation.
Email: zarina@unisza.edu.my

Nurul I. Sarkar is a Computer Scientist specialising in network design, modelling, and performance evaluation. He is currently a Professor and Director of the Networking and Security Research Centre at the Auckland University of Technology (AUT), New Zealand. He holds a PhD in Electrical, Computer and Software Engineering from the University of Auckland. Before this, he completed his master's qualifications in Electronics in 1991 and Computer Science in 1996 from the University of Otago and the University of Canterbury, respectively. Prof Sarkar has developed a strong pedagogy in completing his NZ Diploma of Teaching in 1997 and Tertiary Teaching in 2000 from the University of Canterbury and AUT, respectively. Prof Sarkar has successfully supervised over 40 research students and has examined over 30 PhD theses (mostly Australian Universities). He is currently a primary supervisor for nine PhD students. Prof Sarkar is a regularly invited keynote speaker, chair, and committee member for various national and international fora. He has authored over 200 refereed articles (16+ Q1 journals since 2018) in network and communication journals, including the IEEE Communications Magazine, IEEE Internet of Things Journal, IEEE Transactions on Vehicular Technology, IEEE Transactions on Network and Service Management, IEEE Transactions on Education, Ad Hoc Networks, Computer Communications, and Computer Networks. He is a research assessor for MBIE and The Royal Society of NZ. "Improving the Performance of Wireless LANs: A Practical Guide" (Taylor & Francis, 2014) is his second book. He has spent periods of research leave in China and Japan in recent years. Prof Sarkar served as conference general co-chair for ITNAC'19 and Technical Programme Committee co-chair for ICOIN'24. In 2017, he was awarded the 'Best Paper Award' from the 31st ICOIN International Conference and several IEEE Grants for the professional development of the members of the broader

university community. He is the Chair of the IEEE Educational Activities Committee. He has been appointed as IEEE STEM Champion in recognition of his outstanding contributions to pre-university STEM education and community development in NZ. Prof Sarkar is a member of ACM and a senior member of IEEE. His research interests include wireless network protocols, cognitive radio ad hoc networks, UAV networks, IoT, and Fog computing.
Email: nurul.sarkar@aut.ac.nz

Appendix I

S. No.	Abbreviation	Description
1	5G	Fifth-Generation
2	AEMA	Aggregated Emergency Message Authentication
3	ACM	Association for Computing Machinery
4	AI	Artificial Intelligence
5	DoS	Denial of Service
6	E-ARP	Efficient, Adaptive, and Robust Protocol
7	EID	Electronic Identifier
8	FANET	Flying Ad hoc Network
9	FWCI	Field-Weighted Citation Impact
10	HistCite	Histiograph Cite
11	ICCT	International Conference on Communication Technology
12	IEEE	Institute of Electrical and Electronics Engineers Inc.
13	IEICE	Institute of Electronics, Information and Communication Engineers
14	IoT	Internet of Things
15	IoV	Internet of Vehicles
16	LAN	Local Area Network
17	MANET	Mobile Ad hoc Network
18	MOBICOM	Mobile Computing and Networking
19	NLP	Natural Language Processing
20	OLSR	Optimized Link State Routing
21	OppNets	Opportunistic Networks
22	PubMed	Player Unknown Battle Mantra Ending In Domination
23	QoS	Quality of Service
24	SCP	Single-Country Publication
25	SDN	Software-Defined Network
26	SLR	Systematic Literature Review
27	SPIE	Society of Photo Instrumentation Engineers
28	TENCON	Technical Conference
29	TP	Total Productivity
30	TPc	Total Publications of a given Country
31	TPi	Total Publications of a given Academic Institution
32	TV	Television
33	VANET	Vehicular Ad hoc Network
34	VOSviewer	Visualization of Similarities
35	Wi-Fi	Wireless Fiber
36	WoS	Web of Science
37	WSN	Wireless Sensor Network
38	UAV	Unmanned Aerial Vehicle